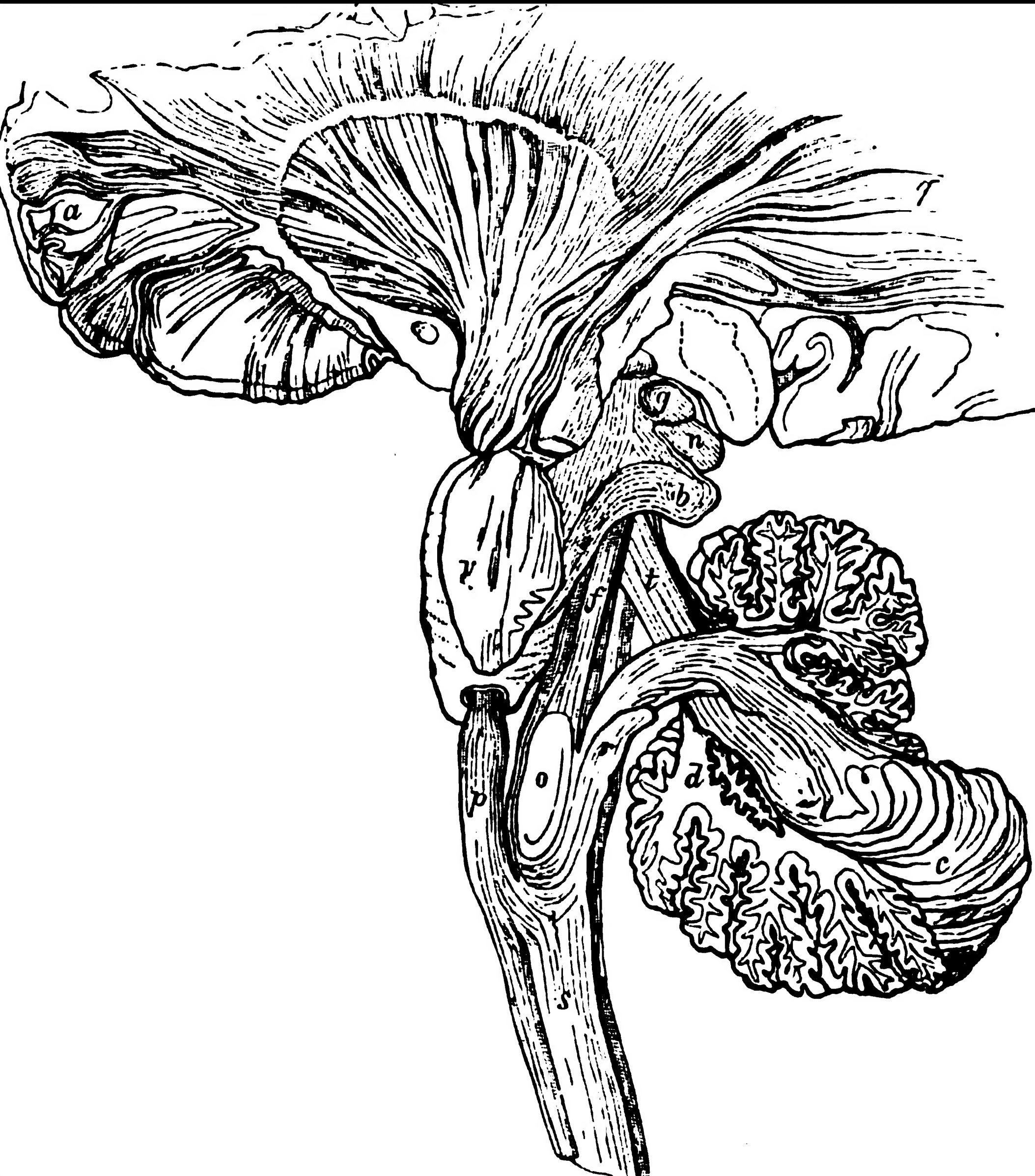

Human physiology

Robley Dunglison

PHYSIOLOGY.

HUMAN

PHYSIOLOGY.

BY

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"Vastissimi studii primas quasi lineas circumscripsi."—HALLER.

WITH

NEARLY FIVE HUNDRED ILLUSTRATIONS.

SEVENTH EDITION,

THOROUGHLY REVISED, AND EXTENSIVELY MODIFIED AND ENLARGED.

IN TWO VOLUMES.

VOL. I.

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Dedication to the First and Second Editions.

TO

JAMES MADISON,

EX-PRESIDENT OF THE UNITED STATES, ETC., ETC.,

ALIKE DISTINGUISHED AS AN ILLUSTRIOUS BENEFACTOR OF HIS COUNTRY,

A ZEALOUS PROMOTER OF SCIENCE AND LITERATURE,

AND THE FRIEND OF MANKIND,

This Work,

INTENDED TO ILLUSTRATE THE FUNCTIONS EXECUTED BY THAT BEING,

WHOSE MORAL AND POLITICAL CONDITION HAS BEEN WITH HIM AN OBJECT OF

ARDENT AND SUCCESSFUL STUDY,

IS, WITH HIS PERMISSION, INSCRIBED,

IN TESTIMONY OF UNFEIGNED RESPECT FOR HIS TALENTS AND PHILANTHROPY,

AND OF GRATITUDE FOR NUMEROUS EVIDENCES OF FRIENDSHIP,

BY HIS OBEDIENT AND OBLIGED SERVANT,

THE AUTHOR.

DIRECTION TO THE BINDER.

The Plates of the System of Respiratory Nerves, and of the Regular or Symmetrical Nerves between pages 88 and 89.

PREFACE TO THE SEVENTH EDITION.

On no previous revision of this work has the author bestowed more care than on the present. In the successive editions, it was, of course, necessary to incorporate the different facts and principles, which had been added from time to time, to the science; and this rendered it difficult to preserve throughout the evenness of style, which is so desirable in every treatise, and more especially in one that is placed in the hands of so many of the younger portion of scientific inquirers. To accomplish this object, the present edition has been subjected to an entire scrutiny, not only as regards the important matters of which it treats, but the language in which they are conveyed.

Perhaps, at no time in the history of the science have observers been more numerous, energetic, and discriminating than in the last few years. Many modifications of fact and inference have consequently taken place, which it has been necessary for the author to record, and to express his views in relation thereto. Especially has he endeavoured to note the phenomena that have presented themselves to the most accurate observers, and to deduce from them laws which may tend to enlarge the boundaries of the science: he has not, however, felt himself at liberty to discard the results of the observations of all former anthropologists, or the opinions they had embraced in regard to the various functions. It not unfrequently, indeed, happens, that in ignorance of the history of the science, views are esteemed new, which had been promulged by earlier investigators. He has, therefore, in an encyclopædiac work like the present, retained many of those opinions, whilst he has laboured to do especial justice to such as have emanated from more recent inquirers. In this respect, his work differs from valuable physiological treatises that are before the public. Whilst, too, he has inserted the main results of the labours of recent histologists, especially such as are directly applicable to physiology, he has not considered it advisable to pursue the subject to such an extent as if the work were on general anatomy, to which histology properly belongs.

On the whole subject of physiology proper, as it applies to the functions executed by the different organs, the present edition, the author flatters himself, will be found to contain the views of the most distinguished physiologists of all periods. The contributions to the science of life have, of late years, been rich and varied; and to collate and weigh them, and to separate the most trustworthy and valued, has been a work of no little discriminating labour,—but to the author a labour of love, inasmuch as they are subjects which he has been long accustomed to investigate: and on which he has annually to treat before the class of Institutes of Medicine of the Jefferson Medical College. The Bibliography, prefixed to the first volume, will exhibit the number and variety of sources of information at home and abroad, which he has had to consult, and will afford a *coup d'œil* of the chief biological investigations, undertaken since the appearance of the last edition more especially, which have so changed the face of the science in regard to certain subjects as to require that they should be re-written.

The rich collection of materials in the possession of his publishers has enabled him to increase greatly the list of illustrations, and to substitute in many cases better; whilst new cuts have been added so as to make the whole number four hundred and seventy-four, in place of three hundred and sixty-eight, as in the last edition. It has been difficult in all cases to assign these to the original projectors; but an effort has been made so to do.

On no former occasion has the author felt as satisfied with his endeavours to have the work on a level with the existing state of the science; and, for the seventh time, he ventures to place it before a profession, which has already done too much honor to his efforts to be useful. His crowning desire, in all his literary undertakings, has been to facilitate the onward course of those who are pressing forward to distinction in a truly learned and difficult profession, and the reception these undertakings have met with has satisfied him, that his labours have been far from fruitless.

ROBLEY DUNGLISON.

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CONTENTS OF VOL. I.

PRELIMINARY OBSERVATIONS.

GENERAL PHYSIOLOGY OF MAN.

BOOK I.

ANIMAL FUNCTIONS, OR FUNCTIONS OF RELATION.

BOOK II.

NUTRITIVE FUNCTIONS.

LIST OF ILLUSTRATIONS IN VOL. I.

HUMAN PHYSIOLOGY.

PROLEGOMENA.

I. NATURAL BODIES.

The extensive domain of Nature is divisible into three great classes: —*Minerals*, *Vegetables*, and *Animals*. This division was universally adopted by the ancients, and still prevails, especially amongst the unscientific. When, however, we carefully examine their respective characteristics, we discover, that the animal and the vegetable resemble each other in many essential particulars. This resemblance has given occasion to the partition of all bodies into two classes: the *Inorganic*, or those not possessing *organs* or instruments adapted for the performance of special actions or functions, and the *Organized*, or such as possess this arrangement.

In all ages, philosophers have attempted to point out a

> "Vast chain of being, which from God began,
> Nature's ethereal, human, angel, man,
> Beast, bird, fish, insect, what no eye can see,
> No glass can reach—"

the links of which chain they have considered to be constituted of all natural bodies; passing by insensible gradations through the inorganic and the organized, and forming a rigid and unbroken series; and in which, they have conceived,

> "——— Each moss,
> Each shell, each crawling insect, holds a rank,
> Important in the plan of Him who framed
> This scale of beings—holds a rank which, lost,
> Would break the chain, and leave behind a gap
> Which Nature's self would rue."

Crystallization has been esteemed by them as the highest link of the inorganic kingdom; the lichen, which encrusts the stone, as but one link higher than the stone itself; the mushroom and the coral as the connecting links between the vegetable and the animal; and the immense space, which separates man—the highest of the mammalia—from his Maker, they have conceived to be occupied in succession by beings of gradually increasing intelligence. If, however, we investigate the matter minutely, we discover that many links of the chain appear widely separated from each other; and that, in the existing

state of our knowledge, the catenation cannot be esteemed rigidly maintained.[1] Let us inquire into the great characteristics of the different kingdoms, and endeavour to describe the chief points in which living bodies differ from those that have never possessed vitality, and into the distinctions between organized bodies themselves.

1. DIFFERENCE BETWEEN INORGANIC AND ORGANIZED BODIES.

Inorganic bodies possess the common properties of matter. Their elements are fixed under ordinary circumstances. Their study constitutes *Physics*, in its enlarged sense, or *Natural Science*. Organized bodies have properties in common with inorganic, but they have likewise others superadded, which control the first in a singular manner. They are beings, whose elements are undergoing constant mutation, and the sciences treating of their structure and functions are *Anatomy* and *Physiology*.

They differ from each other in—

1. *Origin.*—Inorganic bodies are not born: they do not arise from a parent: they spring from the general forces of matter,—the particles being merely in a state of aggregation, and their motions regulated by certain fixed and invariable laws. The animal and the vegetable, on the other hand, are products of generation; they must spring from beings similar to themselves; and they possess the *force of life*, which controls the ordinary forces of matter. Yet it has been supposed, that they are capable of creating life; in other words, that a particular organization presupposes life. This is not the place for entering into the question of generation. It will be sufficient at present to remark, that in the upper classes of animals, the necessity of a parent cannot be contested; the only difficulty that can possibly arise regards the very lowest classes; and analogy warrants the conclusion, that every living being must spring from an egg or a seed.

2. *Shape.*—The shape of inorganic bodies is not fixed in a determinate manner. It is true, that by proper management every mineral can be reduced to a primitive nucleus, which is the same in all minerals of like composition; still, the shape of the mineral, as it presents itself to us, differs. Carbonate of lime, for example, although it may always be reduced to the same primitive nucleus, assumes various appearances; —being sometimes rhomboidal; at others, in regular hexahedral prisms; —in solids, terminated by twelve scalene triangles, or in dodecahedrons, whose surfaces are pentagons. In organized bodies, on the contrary, the shape is constant. Each animal and vegetable has the one that characterizes its species, so that no possible mistake can be indulged; and this applies not only to the whole body, but to every one of its parts, numerous as they are.

3. *Size.*—The size of an inorganic body is by no means fixed. It may be great, or small, according to the quantity present of the particles that have to form it. A crystal, for example, may be minute, or the contrary, according to the number of saline particles in the solution. On the other hand, organized bodies attain a certain size,—at

[1] Fleming's Philosophy of Zoology, i. 4. Edinburgh, 1822.

times by a slow, at others by a more rapid growth,—but in all cases the due proportion is preserved between the various parts,—between the stem and the root, the limb and the trunk. Each vegetable and each animal has its own size, by which it is known; and although we occasionally meet with dwarf or gigantic varieties, these are unfrequent, and mere exceptions establishing the position.

4. *Chemical character.*—Great difference exists between inorganic and organized bodies in this respect. In the mineral kingdom are found all the elementary substances, or those which chemistry, at present, considers *simple;* amounting to at least sixty-three. They are as follows:—*Non-metallic bodies.* Oxygen, hydrogen, nitrogen, sulphur, selenium, phosphorus, chlorine, iodine, bromine, fluorine, carbon, boron, silicon. *Metals.* Potassium, sodium, lithium, calcium, magnesium, barium, strontium, aluminium, glucinium, zirconium, yttrium, thorium, iron, manganese, zinc, cadmium, lead, tin, copper, bismuth, mercury, silver, gold, platinum, rhodium, palladium, osmium, iridium, nickel, cobalt, uranium, cerium, antimony, arsenic, chromium, molybdenum, tungsten, columbium, tellurium, titanium, vanadium, lantanium, didymium, erbium, terbium, pelopium, niobium, ruthenium, norium, and ilmenium. In the organized, a few only of these elements of matter are met with, viz., oxygen, hydrogen, azote, carbon, sulphur, phosphorus, chlorine, fluorine, potassium, sodium, calcium, silicium, aluminium, iron, manganese, titanium, and arsenic.

The composition of inorganic bodies is more simple; several consist of but one element; and, when composed of more, the combination is rarely higher than ternary. Organized bodies, on the other hand, are never simple, nor even binary. They are always at least ternary or quaternary. The simplest vegetable consists of a union of oxygen, carbon, and hydrogen; the simplest animal, of oxygen, hydrogen, carbon, and nitrogen.

The composition of the mineral, again, is constant. Its elements have entirely satisfied their affinities; and all remains at rest. In the organized kingdom, the affinities are not satisfied; compounds are formed to be again decomposed; and this happens from the earliest period of fœtal formation till the cessation of life: all is in commotion, and the chemical character of the corporeal fabric incessantly undergoing modification. This applies to every organized body; and, accordingly, change of some kind is essential to our idea of active life. In the case of the seed, which has remained unaltered for centuries, and subsequently vegetates under favourable circumstances, life may be considered to be dormant or suspended. It possesses vitality, or the power of being excited to active life under favouring influences.

In chemical nomenclature, the term *element* has a different acceptation, according as it is applied to inorganic or organic chemistry. In the former, it means a substance, which, in the present state of science, does not admit of decomposition. We say, "in the present state of the science," for several bodies, now esteemed compound, were, not many years ago, classed amongst the simple or elementary. It is not much more than thirty years since the alkalies were found to be composed of two elements. Previously, they were considered simple. In

the animal and the vegetable, we find substances, also called *elements*, but with the epithet *organic* prefixed, because they are only found in *organized* bodies; and are therefore the exclusive products of organization and life. For example, in both animals and vegetables we meet with oxygen, hydrogen, carbon, nitrogen, and different metallic substances: these are *chemical* or *inorganic elements*. We further meet with albumen, gelatin, fibrin, osmazome, &c., substances which constitute the various organs, and have, therefore, been termed *organic elements* or *compounds of organization;* yet they are capable of decomposition; and in one sense, therefore, not elementary.

In the inorganic body, all the elements, that constitute it, are formed by the agency of general chemical affinities; but, in the organized, the formation is produced by the force that presides over the formation of the organic elements themselves,—the force of life. Hence, the chemist is able to recompose many inorganic bodies; whilst the products of organization and life set his art at defiance.

The different parts of an inorganic body enjoy an existence independent of each other; whilst those of the organized are materially dependent. No part can, indeed, be injured without the mass and the separated portion being more or less affected. If we take a piece of marble, which is composed of carbonic acid and lime, and break it into a thousand fragments, each portion will be found to consist of carbonic acid and lime. The mass will be destroyed; but the pieces will not suffer from the disjunction. They will continue as fixed and unmodified as at first. Not so with an organized body. If we tear the branch from a tree, the stem itself participates more or less in the injury; the detached branch speedily undergoes striking changes; it withers; becomes shrivelled; and, in the case of the succulent vegetable, undergoes decomposition; certain of its constituents, no longer held in control by vital agency, enter into new combinations, are given off in the form of gas, and the remainder sinks to earth.

Changes, no less impressive, occur in the animal when a limb is separated from the body. The parent trunk suffers; the system recoils at the first infliction of the injury, but subsequently arouses itself to a reparatory effort,—at times with such energy as to destroy its own vitality. The separated limb, like the branch, is given up, uncontrolled, to new affinities; and putrefaction soon reduces the mass to a state in which its previously admirable organization is no longer perceptible. Some of the lower classes of animals may, indeed, be divided with impunity; and with no other effect than that of multiplying the animal in proportion to the number of sections; but these cases are exceptions; and we may regard the destructive process,—set up when parts of organized bodies are separated,—as one of the best modes of distinction between the inorganic and organized classes.

5. *Texture.*—In this respect the inorganic and organized differ considerably,—a difference which has given rise to their respective appellations. To the structure of the latter class only can the term *texture* be with propriety applied. If we examine a vegetable or animal substance with attention, we find, that it has a regular and determinate arrangement or structure; and readily discover, that it consists of va-

rious parts;—in the vegetable, of wood, bark, leaves, roots, flowers, &c.; and in the animal, of muscles, nerves, vessels, &c.; all of which appear to be instruments or *organs* for special purposes in the economy. Hence, the body is said to be *organized*, and the result, as well as the process, is often called *organization*. Properly, *organization* means the process by which an organized being is formed; *organism*, the result of such process, or organic structure.

The particles of matter in an organized body, in many instances, constitute fibres, which interlace and intersect each other in all directions, and form a spongy areolar texture or tissue, of which the various organs of the body are composed. These fibres, and indeed every organized structure, are considered by modern histologists to be formed originally from cellgerms or cytoblasts: the resulting cells assuming an arrangement appropriate to the particular tissue. "A texture," says Mr. Goodsir,[1] "may be considered either by itself, or in connexion with the parts which usually accompany it. These subsidiary parts may be entirely removed without interfering with the anatomical constitution of the texture. It is essentially non-vascular;—neither vessels nor nerves entering into its intimate structure. It possesses in itself those powers by which it is nourished, produces its kind, and performs the actions for which it is destined, the subsidiary or superadded parts supplying it with materials, which it appropriates by its own inherent powers, or connecting it in sympathetic and harmonious action with other parts of the organism to which it belongs. In none of the textures are these characters more distinctly seen than in the osseous. A well-macerated bone is one of the most easily made, and at the same time one of the most curious of anatomical preparations. It is a perfect example of a texture completely isolated; the vessels, nerves, membranes, and fat, are all separated; and nothing is left but the non-vascular osseous substance."

In the inorganic substance the mass is homogeneous; the smallest particle of marble consists of carbonic acid and lime; and all the particles concur alike in its formation and preservation.

Lastly, while an inorganic body, of a determinate species, has always a fixed composition, the living being, although constituting a particular species, may present individual differences, which give rise in the animal, to various *temperaments*, *constitutions*, *&c.*

6. *Mode of preservation.*—Preservation of the species is, in organized bodies, the effect of reproduction. As regards individual preservation, that of the mineral is dependent upon the same actions that effected its formation; on the persistence of the affinities of cohesion and combination that united its various particles. The animal and the vegetable, on the other hand, are maintained by a mechanism peculiar to themselves. From the bodies surrounding them they lay hold of nutritious matter, which, by a process of elaboration, they assimilate to their own composition; at the same time, they are constantly absorbing

[1] Anatomical and Pathological Observations, p. 64, Edinburgh, 1845. See also Schwann, Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants; translated by Henry Smith. Sydenham Society edit. Lond. 1847.

or taking up particles of their own structure, and throwing them off. The actions of composition and decomposition are constant whilst life persists; although subject to particular modifications at different periods of existence, and under different circumstances.

Again:—the inorganic and organized are alike subject to changes during their existence; but the character of these changes, in the two classes, differs essentially. The mineral retains its form, unless acted upon by some mechanical or chemical force. Within, all the particles are at rest, and no internal force exists, which can subject them to modification. There is no succession of conditions that can be termed *ages*. How different is the case with organized bodies! Internally, there is no rest; from birth to death all is in a state of activity. The plant and the animal are subject to incessant changes. Each runs through a succession of conditions or *ages*. We see it successively developе its structure and functions, attain maturity, and finally decay.

Characteristic differences likewise exist in the external conformation of the beings of the two divisions, as well as in their mode of increase. Inorganic bodies have no covering to defend them; no exterior envelope to preserve their form; a stone is the same at its centre as at its circumference; whilst organized bodies are protected by an elastic and extensible covering, differing from the parts beneath, and inservient to valuable purposes in the economy.

Every change to which an inorganic body is liable must occur at its surface. It is there that the particles are added or abstracted when it experiences increase or diminution. Increase—for *growth* it can scarcely be termed—takes place by *accretion* or *juxtaposition*, that is, by the successive application of fresh particles upon those that form the nucleus; and diminution in bulk is produced by the removal of the external layers or particles. In organized substances, increase or growth is caused by particles deposited internally, and diminution by particles subtracted from within. We see them, likewise, under two conditions, to which there is nothing similar in the mineral kingdom—*health*, and *disease*. In the former, the functions are executed with freedom and energy; in the latter, with oppression and restraint.

7. *Termination.*—Every body, inorganic or organized, may cease to exist, but the mode of cessation varies greatly in the two classes. The mineral is broken down by mechanical violence; or it ceases to exist in consequence of modifications in the affinities, which held it concrete. It has no fixed duration; and its existence may be terminated at any moment, when the circumstances, that retained it in aggregation, are destroyed. The vegetable and the animal, on the other hand, carry on their functions for a period only which is fixed and determinate for each species. For a time, new particles are deposited internally. The bulk is augmented, and the external envelope distended, until maturity or full developement is attained; but, after this, decay commences; the functions are exerted with gradually diminishing energy; the fluids decrease in quantity; and the solids become more rigid,—circumstances premonitory of the cessation of vitality. This term of duration is different in different species. Whilst many of the lower classes of ani-

mals and vegetables have but an ephemeral existence, some of the more elevated individuals of the two kingdoms outlive a century.

8. *Motive forces.*—Lastly, observation has satisfactorily proved, that there are certain forces, which affect matter in general, inorganic as well as organized; and that, in addition to these, organized bodies possess a peculiar force or forces, which modify them in a remarkable manner. Hence, we have *general forces;* and *special* or *vital;* the *first* acting upon all matter, the dead and the living, and including the forces of *gravitation*, *cohesion*, *chemical affinity*, &c.; the *latter* appertaining exclusively to living beings.

Such are the chief distinctions to be drawn between the two great divisions of natural bodies; the inorganic and the organized. By the comparison which has been instituted, the objects of physiology have been indicated. To inquire into the mode in which a living being is *born*, *nourished*, *reproduced*, and *dies*, is the legitimate object of the science. We have, however, entered only into a comparison between the inorganic and the organized. The two divisions constituting the latter class differ also materially from each other. Into these differences we shall now inquire.

2. DIFFERENCE BETWEEN ANIMALS AND VEGETABLES.

The distinctions between the divisions of organized bodies are not so rigidly fixed, or so readily appreciated, as those between the inorganic and the organized. There are certain functions possessed by both; hence called *vegetative*, *plastic*, or *organic*,—nutrition and reproduction, for example; but vegetables are endowed with these only. All organized bodies must have the power of assimilating foreign matters to their own substance, and of producing a living being similar to themselves; otherwise, the species, having a limited duration, would perish. In addition to these common functions, animals have *sensation* and *voluntary* motion; by the possession of which they are said to be *animated.* Hence, they are termed *animals*, and the condition is called *animality.* This division of the functions into *animal* and *organic* has been adopted, with more or less modification, by most physiologists.

Between animals and vegetables, situate high in their respective scales, no confusion can exist. The characters are obvious at sight. No one can confound the horse with the oak; the butterfly with the potato. It is on the lower confines of the two kingdoms, that we are liable to be deceived. Many of the zoophytes have alternately been considered vegetable and animal; but we are generally able to classify any doubtful substance with accuracy; and the following are the principal points of difference.

1. *Composition.*—It was long supposed, that the essential difference between animal and vegetable substances consists in the former containing nitrogen; whilst the latter do not. Modern researches have, however, satisfactorily shown, that the organized portions of animals and vegetables are essentially alike; and consist of the four elements,—carbon, oxygen, hydrogen, and nitrogen; whilst the unorganized—as the fat of the animal, and the starch of the vegetable—are composed of three elements only—carbon, oxygen, and hydrogen. Still, their

intimate composition must vary greatly; for, when burning, the animal substance is readily known from the vegetable;—a fact, which, as Dr. Fleming[1] has remarked, is interesting to the young naturalist, if uncertain to which kingdom to refer any substance met with in his researches. The smell of a burnt sponge, of coral, or other zoophytic animal, is so peculiar, that it can scarcely be mistaken for that of a vegetable body in combustion. According to Mulder,[2] there is this real difference between plants and animals in composition, that cellulose ($C^{24}H^{21}O^{21}$) forms the principal part of the cellular mass in plants; whilst in animals the primary material is gelatin ($C^{13}H^{10}N^{2}O^{5}$); and to this rule, he says, no exception has yet been discovered either among animals or plants.

2. *Texture.*—In this respect, important differences are observable. Both animals and vegetables consist of solid and fluid parts. In the former, however, the fluids bear a large proportion: in the latter, the solids. This is the cause, why decomposition occurs so much more rapidly in the animal than in the vegetable; and in the succulent more than in the dry vegetable. If we analyze the structure of the vegetable, we cannot succeed in detecting more than one elementary tissue, which is *vesicular* or *areolar*, or arranged in vesicles or areolæ, and appears to form every organ of the body; whilst, in the animal, we discover at least three of these anatomical elements, the *areolar*—analogous to that of the vegetable;—the *muscular*, and the *nervous*. The vegetable again has no great splanchnic cavities containing the chief organs of the body. It has a smaller number of organs, and none that are destined for sensation or volition; in other words, no brain, no nerves, no muscular system; and the organs of which it consists are simple, and readily convertible into each other.

But these differences in organization, striking as they may appear, are not sufficient for rigid discrimination, as they are applicable only to the upper classes of each kingdom. In many vegetables, the fluids appear to preponderate over the solids; numerous animals are devoid of muscular and nervous tissues, and apparently of vessels and distinct organs; whilst MM. Dutrochet,[3] Brachet,[4] and others,[5] admit the existence of a rudimental nervous system even in vegetables.

3. *Sensation and voluntary motion.*—There is one manifest distinction between animals and vegetables. Whilst the latter receive their nutrition from the objects around them—irresistibly and without volition, or the participation of mind; and whilst the function of reproduction is effected without the union of the sexes, both volition and sensation are necessary for the nutrition of the former, and for acts that are requisite for the reproduction of the species. Hence, the necessity

[1] Philosophy of Zoology, i. 41. Edinburgh, 1822.

[2] The Chemistry of Animal and Vegetable Physiology; translated by Fromberg, p. 91. Edinburgh and London, 1849.

[3] Recherches Anatomiques et Physiologiques sur la Structure Intime des Animaux, et des Végétaux, et sur leur Motilité. Paris, 1824.

[4] Recherches Expérimentales sur les Fonctions du Système Nerveux Ganglionnaire, &c. 2d édit. Paris et Lyons, 1837.

[5] Sir J. E. Smith, Introduction to Botany, 7th edit., by Sir W. J. Hooker, p. 40. Lond. 1833.

of two faculties or functions in the animal, that are wanting in the vegetable,—*sensibility*, or the faculty of consciousness and feeling; and *motility*, or the power of moving at will the whole body or any of its parts. Vegetables are possessed of *spontaneous*, but not of *voluntary* motion. Of the former we have numerous examples in the direction of the branches and upper surfaces of the leaves, although repeatedly disturbed, to the light; and in the unfolding and closing of flowers at stated periods of the day. This, however, is distinct from the sensibility and motility that characterize the animal. By *sensibility* man feels his own existence,—becomes acquainted with the universe,—appreciates the bodies that compose it; and experiences all the desires and inward feelings that solicit him to the performance of those external actions, which are requisite for his preservation as an individual, and as a species; and by *motility* he executes those external actions which his sensibility may suggest to him.

By some naturalists it has been maintained, that those plants, which are borne about on the waves, and fructify in that situation, exhibit examples of the locomotility, which is described as characteristic of the animal. One of the most interesting novelties in the monotonous occurrences of a voyage across the Atlantic towards the Gulf of Florida is the almost interminable quantity of *Fucus natans*, *Florida weed* or *Gulf weed*, with which the surface of the ocean is covered. But how different is this from the locomotion of animals! It is a subtlety to conceive them identical. The weed is passively and unconsciously borne whithersoever the winds and the waves may urge it; whilst animal locomotion requires the direct agency of volition, of a nervous system that can excite, and of muscles that can act under such excitement.

The *spontaneity* and *perceptivity* of plants must also be explained in a different manner from the elevated function of sensibility on which we shall have to dwell. These properties must be referred to the fact of certain vegetables being possessed of the faculty of contracting on the application of a stimulus, independently of sensation or consciousness. If we touch the leaf of the sensitive plant, *Mimosa pudica*, the various leaflets collapse in rapid succession. In the barberry bush, *Berberis vulgaris*, we have another example of the possession of this faculty. In the flower, the six stamens, spreading moderately, are sheltered under the concave tips of the petals, till some extraneous body, as the feet or trunk of an insect in search of honey, touches the inner part of each filament, near the bottom. The susceptibility of this part is such, that the filament immediately contracts, and strikes its anther, full of pollen, against the stigma. Any other part of the filament may be touched without this result, provided no concussion be given to the whole. After a while, the filament retires gradually, and may be again stimulated; and when each petal, with its annexed filament, has fallen to the ground, the latter, on being touched, shows as much sensibility as ever.[1]

These singular effects are produced by the power of *contractility* or

[1] Sir J. E. Smith's Introduction to Botany, p. 325.

irritability, the nature of which will fall under consideration hereafter. It is possessed equally by animals and vegetables, and is essentially organic and vital. This power, we shall see, needs not the intervention of volition: it is constantly exerted in the animal without consciousness, and therefore necessarily without volition. Its existence in vegetables does not, consequently, demonstrate that they are possessed of consciousness.

4. *Nutrition.*—A great difference exists between plants and animals in this respect. The plant, being fixed to the soil, cannot search after food. It must be passive; and obtain its supplies from the materials around, and in contact with it; and the absorbing vessels of nutrition must necessarily open on its exterior. In the animal, on the other hand, the aliment is scarcely ever found in a state fit for absorption: it is crude, and in general—Ehrenberg[1] thinks always—requires to be received into a central organ or *stomach*, for the purpose of undergoing changes, by a process termed *digestion*, which adapts it for the nutrition of the individual. The absorbing vessels of nutrition arise, in this case, from the internal or lining membrane of the alimentary tube. The analogy that exists between these two kinds of absorption is great, and had not escaped the attention of the ancients:—*Quemadmodum terra arboribus, ita animalibus ventriculus sicut humus*," was an aphoristic expression of universal reception. With similar feelings, Boerhaave asserts, that animals have their *roots* of nutrition in their intestines; and Dr. Alston[2] has fancifully termed a plant an *inverted animal.*

After all, however, the most essential difference consists in the steps that are preliminary to the reception of food. These, in the animal, are voluntary,—requiring prehension; often locomotiou; and always consciousness.

5. *Reproduction.*—In this function we find a striking analogy between animals and vegetables; but differences exist, which must be referred to the same cause that produced many of the distinctions already pointed out,—the possession, by the animal, of sensibility and locomotility. For example, every part of the generative act, as before remarked, is, in the vegetable, without the perception or volition of the being:—the union of the sexes, fecundation, and the birth of the new individual are alike automatic. In the animal, on the other hand, the approximation of the sexes is always voluntary and effected consciously:—the birth of the new individual being not only perceived, but somewhat aided by volition. Fecundation alone is involuntary and irresistible.

Again, in the vegetable the sexual organs do not exist at an early period; and are not developed until reproduction is practicable. They are capable of acting for once only, and perish after fecundation; and if the plant be vivacious, they fall off after each reproduction, and are annually renewed. In the animal, on the contrary, they exist from the earliest period of fœtal development, survive repeated fecundations, and continue during the life of the individual.

[1] Edinb. New Philosophical Journal, for Sept. 1831; and Jan. 1838, p. 232.
[2] Tirocinium Botanicum Edinburgense, 8vo., Edinb. 1753.

Lastly, the possession of sensibility and locomotility leads to other characteristics of animated beings. These functions are incapable of constant, unremitting exertion. *Sleep*, therefore, becomes necessary. The animal is also capable of *expression*, or of *language*, in a degree proportionate to the extent of his sensibility, and of his power over the beings that surround him.

But these differences in function are not so discriminate as they may appear at first. There are many animals, that are as irresistibly attached to the soil as the vegetables themselves. Like the latter, they must, of necessity, be compelled to absorb their food in the state in which it is presented to them. Sensibility and locomotility appear, in the zoophyte, to be no more necessary than in the vegetable. No nervous, no muscular system is required; and, accordingly, none can be traced in them; whilst many of those spontaneous motions of the vegetable, to which allusion has been made, have been considered by some to indicate the first rudiments of sensibility and locomotility; and Linnæus[1] has regarded the closure of the flowers towards night as the *sleep*, and the movements of vegetables, for the approximation of the sexual organs, as the *marriage*, of plants.

II. GENERAL PHYSIOLOGY OF MAN.

The observations made on the differences between animals and vegetables have anticipated many topics, that would require consideration under this head. These general properties, which man possesses along with other animals, have been referred to in a cursory manner. They will now demand a more special investigation.

1. MATERIAL COMPOSITION OF MAN.

The detailed study of human organization is the province of the anatomist,—of its intimate composition, that of the chemist. In explaining the functions executed by the various organs, the physiologist will frequently have occasion to trench upon both.

The *bones*, in the aggregate, form the *skeleton*. The base of the skeleton is a series of *vertebræ*, with the *skull* as a capital,—itself regarded as a vertebra. This base is situate on the median line through the whole trunk, and contains a cavity, in which are lodged the brain and spinal marrow. On each side of this, other bones, which by some have been called *appendices*, are arranged in pairs. Upon the skeleton are placed *muscles*, for moving the different parts of the body; and for changing its situation with regard to the soil. The body is divided into *trunk* and *limbs*. The *trunk*, which is the principal portion, is composed of three *splanchnic* cavities, the *abdomen*, *thorax*, and *head*, situate one above the other. They contain the most important organs of the body,—those that effect the functions of sensibility, digestion, respiration, circulation, &c. The *head* comprises the *face*, in which are the organs of four of the senses—sight, hearing, smell, and taste,—and the *cranium*, which lodges the brain—the organ of the mental manifestations, and the most elevated part of the nervous system. The

[1] Amœnit. Academ., tom. iv.

thorax or *chest* contains the lungs—organs of respiration—and the heart, the central organ of the circulation. The *abdomen* contains the principal organs of digestion, and (if we include in it the *pelvis*), those of the urinary secretion and of generation. Of the *limbs*, the *upper*, suspended on each side of the thorax, are instruments of prehension; and are terminated by the hand, the great organ of touch. The *lower* are beneath the trunk; and are agents for supporting the body, and for locomotion. *Vessels*, emanating from the heart, are distributed to every part,—conveying to them the blood necessary for their life and nutrition: these are the *arteries*. Other vessels communicate with them, and convey the blood back to the heart—the *veins;* whilst a third set arise in the tissues, and convey into the circulation, by a particular channel, a fluid called *lymph*—whence they derive the name *lymphatics*. *Nerves*, communicating with the great central masses of the nervous system, are distributed to every part; and lastly, a membrane or layer, possessed of acute sensibility—the *skin*—serves as an outer envelope to the whole body.

It was before observed, that two kinds of *elements* enter into the composition of the body—the *chemical* or *inorganic;* and the *organic*, which are *compound*, and formed only under the force of life.

The chief CHEMICAL or INORGANIC ELEMENTS, met with, are—oxygen, hydrogen, carbon, nitrogen, phosphorus, calcium; and, in smaller quantity, sulphur, iron, manganese, calcium, silicium, aluminium, chlorine; also, sodium, magnesium, &c. &c.

1. *Oxygen.*—This is widely distributed in the solids and fluids; and a constant supply of it from the atmosphere is indispensable to animal life. It is almost always found combined with other bodies; often in the form of carbonic acid,—that is, united with carbon. In a separate state it is met with in the air-bag of fishes, in which it is found varying in quantity, according to the species, and the depth at which the fish has been caught.

2. *Hydrogen.*—This gas occurs universally in the animal kingdom. It is a constituent of all the fluids, and of many of the solids; and is generally in a state of combination with carbon. In the human intestines it has been found pure, as well as combined with carbon and sulphur.

3. *Carbon.*—This substance is met with under various forms, in both fluids and solids. It is most frequently found under that of carbonic acid. Carbonic acid has been detected in an uncombined state in urine by Prout; and in the blood by Vogel.[1] It exists in the intestines of animals; but is chiefly met with in animal bodies, in combination with the alkalies or earths; and is emitted by all animals in the act of respiration.

4. *Nitrogen.*—This gas is likewise widely distributed as a component of animal substances, and especially of the tissues. It occurs in an uncombined state, in the swimming-bladder of certain fishes.

5. *Phosphorus* is an essential constituent of neurine; and is found united with oxygen, in the state of *phosphoric acid*, in many of the

[1] Annals of Philosophy, vii. 56.

solids and fluids. It is this acid that is combined with the earthy matter of bones; and with potassa, soda, ammonia, and magnesia, in other parts. It is supposed to give rise to the luminousness of certain animals—as of the firefly, *Pyrosoma Atlanticum*, &c.—but nothing precise is known on this subject.

6. *Calcium.*—This metal is found in the animal economy only in the state of oxide—lime; and it is generally united with phosphoric or carbonic acid. It is the earth, of which the hard parts of animals are constituted.

7. *Sulphur* is not met with extensively in animal solids or fluids; nor is it often found free, but usually in combination with oxygen united to soda, potassa, or lime. It seems to be an invariable concomitant of albumen; and is found in the intestines, in the form of sulphuretted hydrogen; and as an emanation from fetid ulcers.

8. *Iron.*—This metal has been detected in the colouring matter of the blood; in bile, and in milk. In the first of these fluids it was, for a long time, considered to be in the state of phosphate or sub-phosphate. Berzelius[1] showed, that this was not the case; that the ashes of the colouring matter always yielded oxide of iron in the proportion of 1-200th of the original mass. That distinguished chemist was, however, unable to detect the condition in which the metal exists in the blood; and could not discover its presence by any of the liquid tests. Subsequently, Engelhart showed, that the fibrin and albumen of the blood, when carefully separated from colouring particles, do not contain a trace of iron; whilst he could procure it from the red corpuscles by incineration. He also succeeded in proving its existence in the red corpuscles by liquid tests; and his experiments were repeated, with the same results, by Rose of Berlin.[2] In milk, iron seems to be in the state of phosphate.

9. *Manganesium* has been found in the state of oxide, along with iron, in the ashes of the hair; in bones, and blood, and also in gall-stones, and in the blood.

10. *Copper* and *lead.*—It was conceived by M. Devergie, that copper and lead may exist naturally in the tissues;[3] but MM. Flandin and Danger, and a commission of the Académie Royale de Médecine of Paris, were unable to confirm the existence of copper; and the results of the investigations of Professor F. de Cattanei di Momo,[4] of Pavia, seem to prove the non-existence of lead also. M. Barse, however, in a paper read before the Royal Academy of Sciences of Paris, in August, 1843, states, that he found both metals in the bodies of two persons, to whom they could not have been given for poisons. The researches of Signor Cattanei di Momo appeared to prove that these metals do not exist in the bodies of new-born children or infants; and M. J. Rossignon has offered a solution as to the probable source of the copper, as he found it not only in the blood and muscles of the dog, but in

[1] Medico-Chirurgical Transact., vol. iii.
[2] Turner's Chemistry, fifth ed., p. 963. London, 1834.
[3] Bullet. de l'Académ. Royale de Médecine, 19 Févr., 1839.
[4] Annali Universali di Medicina, Aprile, 1840; cited in British and Foreign Medical Review, Jan., 1841, p. 226.

many articles of vegetable and animal food; in gelatin from bones, for example, in sorrel, chocolate, bread, coffee, succory, madder, and sugar. The ashes obtained from starch sugar yielded 4 per cent. of copper; those of gelatin, 0·03 per cent.; and those of bread, 0·005 to 0·008 per cent.[1] It is now generally considered to be present in the human liver,[2] and M. E. Millon[3] asserts, that human blood invariably contains lead, copper, silica, and manganese.

11. *Silicium.*—Silica is found in the hair, bones, blood, urine, and in urinary calculi.

12. *Chlorine.*—In combination with hydrogen, and forming *chlorohydric acid*, chlorine is met with in most of the animal fluids. It is generally united with soda. Free chlorohydric acid has also been found by Dr. Prout[4] in the stomach of the rabbit, hare, horse, calf, and dog; and he has discovered the same acid in the sour matter ejected from the stomachs of those labouring under indigestion. Mr. Children, and Messrs. Tiedemann and Gmelin,[5] made similar observations; and Professor Emmet and the author[6] found it in considerable quantity in the healthy gastric secretions of man.

13. *Fluorine.*—This simple substance has been found combined with calcium—*fluoride of calcium*—in the enamel of the teeth, bones, and urine.

14. *Sodium.*—Oxide of sodium, *soda*, forms part of all the fluids. It has never been discovered in a free state; but is united (without an acid), to albumen. Most frequently, it is combined with chlorine, and phosphoric acid; less frequently, with lactic, carbonic, and sulphuric acids. Chloride of sodium is contained in most of the animal secretions; and from its decomposition may result the chlorohydric acid of the gastric juice, and a part the soda of the bile and other fluids.

15. *Potassium.*—The oxide, *potassa*, is found in many animal fluids, but always united with acids—sulphuric, chlorohydric, phosphoric, &c. It is much more common in the vegetable kingdom; and hence one of its names—*vegetable alkali.*

16. *Magnesium.*—The oxide, *magnesia*, exists sparingly in bones, and in some other parts; but always in combination with phosphoric acid, and appears to be always associated with calcium.

17. *Aluminium.*—Alumina is said by Morichini to exist in the enamel of the teeth. Fourcroy and Vauquelin found it in the bones; and John, in white hairs. According to Schlossberger, it is in the flesh of fishes.[7]

18. *Titanium.*—Dr. Rees affirms, that he detected it in salts obtained from the supra-renal capsules.

[1] Lond. Med. Gaz., Dec. 1, 1843, from Gazette Médicale de Paris, and Mr. Paget, Rep. on Anatomy and Physiology, 1843–4, in Brit. and For. Med. Rev., Jan., 1845, p. 249.

[2] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 29, Philad., 1849.

[3] Comptes Rendus, Paris, 1848.

[4] Philosoph. Transact. for 1824, p. 45.

[5] Recherches Expérimentales, &c., sur la Digestion, trad. par A. G. L. Jourdan. Art. 4, p. 94, Paris, 1827.

[6] See under the head of "Digestion," and the author's Human Health, p. 191, Philadelphia, 1844.

[7] Henle, Allgemeine Anatomie, s. 4. Leipz., 1841, or Jourdan's translation, i. 2, Paris, 1843.

19. *Arsenic.*—It was asserted by M. Orfila, that arsenic exists naturally in the human body; and that it is a normal constituent of human bones. Subsequent experiments, however, performed by M. Orfila himself, have shown that there was fallacy in his first observations.[1]

ORGANIC ELEMENTS, *proximate principles* or *compounds of organization*, are combinations of two or more of the elementary substances, in definite proportions. Formerly, four only were admitted—*gelatin*, *fibrin*, *albumen*, and *oil*. Of late, however, organic chemistry has pointed out others, which are divided into two classes,—*first*, those that contain nitrogen, as albumen, gelatin, fibrin, osmazome, mucus, casein, urea, uric acid, red colouring principle of the blood, yellow colouring principle of the bile, &c.; and *secondly*, those that do not contain azote,—as olein, stearin, the fatty matter of the brain and nerves, acetic, oxalic, benzoic, and lactic acids, sugar of milk, sugar of diabetes, picromel, colouring principle of the bile, and that of other solids and liquids, &c.

a. *Organic Elements that contain Nitrogen.*

1. *Protein.*—Modern researches appear to have shown, that the chief proximate principles of animal tissues, and those that have been regarded as highly nutritious among vegetables, have almost identically the same composition; and are modifications of a principle to which Mulder—its discoverer—gave the name *Protein*. If animal albumen, fibrin, or casein, be dissolved in a moderately strong solution of caustic potassa, and the solution be exposed for some time to a high temperature, these substances are decomposed. The addition of acetic acid to the solution causes, in all three, the separation of a gelatinous translucent precipitate, which has exactly the same character and composition, from whichsoever of the solutions it is obtained. It may be procured, too, from globulin of blood, and from vegetable albumen.[2]

The chemical relations of protein, especially in regard to oxygen, are full of interest. The products of its oxidation, *binoxide* and *tritoxide of protein*, occur constantly in the blood. They are formed in the lungs from fibrin; which, in a moist state, possesses the property of absorbing oxygen. Fibrin, oxidized in the lungs, is, according to Mulder, the principal—if not the only—carrier of the oxygen of the air in the blood to the tissues; and it is from this substance especially, that the secretions are formed. In inflammatory conditions, a much larger quantity of protein in an oxidized state is contained in the blood than in health; and this, according to Mulder, gives occasion to the buffy coat.[3]

The following substances may be regarded as modifications or combinations of protein. They are composed of it and of a small quantity of phosphorus, or of sulphur, or both.[4]

[1] Rapport de l'Académie Royale de Médecine, Juillet, 1841; Taylor's Medical Jurisprudence, by Dr. Griffith, p. 133, Philad., 1845; and Simon, Animal Chemistry, Sydenham Soc. edit., p. 4, Lond., 1845, or Amer. edit., Philad., 1845.

[2] Liebig, Animal Chemistry, Gregory's and Webster's edit., p. 100. Cambridge, 1842.

[3] Simon's Animal Chemistry, Sydenham Soc. edit., p. 12, London, 1845; or American edit., Philadelphia, 1845.

[4] Henle, op. cit., p. 31.

a. *Albumen.*—This is one of the most common organic constituents; and appears under two forms—*liquid* and *concrete.* In its purest state, the former is met with in white of egg—whence its name; in the serum of the blood; the lymph of the absorbents; the serous fluid of the great splanchnic cavities and of the areolar membrane; and in the synovial secretion. It is colourless and transparent; without smell or taste; and is coagulated by acids, alcohol, ether, metallic solutions, infusion of galls, and by a temperature of 158° Fahrenheit. A very dilute solution, however, does not become turbid until it is boiled. It is excreted by the kidneys in large quantities, in the disease, which, owing to its presence in the urine, has been called *Albuminuria.*

Concrete, coagulated, or *solid albumen,* is white; tasteless; and elastic; insoluble in water, alcohol, or oil; but readily soluble in alkalies.

Albumen is always combined with soda. It exists, in abundance—both the liquid and concrete—in different parts of the animal body. Hair, nails, and horn consist of it; and it is, in some form or other, a constituent of many tumours.

In the advanced chyliferous vessels albumen is found in quantity; and it is probable, that every proteinaceous aliment, and perhaps those that are not proteinaceous, is reduced to the form of albumen in the process of digestion, so that it becomes the nutritious constituent of whatever fluid is absorbed for the formation of tissue. It is not, of itself, organizable; requiring first to be converted into fibrin.

b. *Fibrin.*—This proximate principle exists in the chyle; enters into the composition of the blood; forms the chief part of muscular flesh; and may be looked upon as one of the most abundant animal substances. It is obtained by beating the blood with a rod, as it issues from a vein. The fibrin attaches itself to each twig in the form of red filaments, which may be deprived of their colour by repeated washing with cold water. Fibrin is solid; white; flexible; slightly elastic; insipid; inodorous; and heavier than water. It is neither soluble in water, alcohol, nor acids; dissolves in liquid potassa or soda, in the cold, without much change; and when warm, becomes decomposed.

Fibrin constitutes the buffy coat of blood; it is thrown out from the blood-vessels, as a secretion, in many cases of inflammation; and becomes subsequently organized.

There is no mode of distinguishing liquid fibrin from liquid albumen, except by the spontaneous coagulation of the former. Consequently, according to Henle,[1] if a liquid does not coagulate of itself, it does not contain fibrin. A very small quantity, however, of fibrin may be so dissolved in serous fluid, that it will not coagulate.[2] The change of albumen to fibrin has been regarded as the first important step in the process of assimilation, fibrin being endowed with much higher organizable properties than albumen. This has been attributed to some influence exerted upon albuminous fluids by the living surfaces over which they pass.

The correspondence of fibrin with albumen is shown by the circum-

[1] Op. cit., p. 38.
[2] Dr. Buchanan, Lond. Med. Gaz. for 1836, pp. 52 and 90, and ibid. for 1845, p. 617.

stance, that it may be wholly dissolved in a solution of nitrate of potassa, and that this solution greatly resembles a solution of albumen, and is coagulated by heat. This happens, however, only to the ordinary fibrin of venous blood. That which is obtained from arterial blood or from the buffy coat; or which has been exposed for some time to the air, is not thus soluble, the difference appearing to depend upon the larger quantity of oxygen contained in the latter; for a solution of venous fibrin in nitre, contained in a deep cylindrical jar, allows a precipitate in fine flocks to fall gradually, provided the air has access to the surface; but not if its access be prevented. This precipitate is insoluble in the solution of nitre, and possesses the properties of arterial fibrin.[1] Hence, as Dr. Carpenter[2] has remarked, it may be inferred, that the fibrin of venous blood most nearly resembles albumen; whilst that of arterial blood, and of the buffy coat, contains more oxygen, and is more highly animalized; and that the matter of the red corpuscles is not the only constituent of the blood, which undergoes a change in the respiratory process.

c. *Casein*, *Caseum*, *Caseous matter*.—This substance exists in greatest abundance in milk; and is the basis of cheese. It is found also in blood, saliva, bile, pancreatic juice; in pus, tubercular matter, &c. To obtain it, milk must be left at rest, at the ordinary temperature, until it is coagulated: the cream that collects on the surface must be taken off; the clot well washed with water, drained upon a filter, and dried. The residuum is pure *casein*. It is a white, insipid, inodorous substance, insoluble in water, but readily soluble in the alkalies, especially in ammonia. It possesses considerable analogy with albumen. Prout ascribes the characteristic flavour of cheese to the presence of caseate of ammonia.

Until recently, it was believed that vegetable albumen and fibrin differ from animal albumen and fibrin; but Mulder showed that this is not the case; and casein, which agrees with the others in composition, has been found by Liebig in the vegetable. *Legumin* is vegetable casein. Of late, the views of Mulder as to the very existence of protein have been combated by Liebig and Th. Fleitmann;[3] but still—as Messrs. Kirkes and Paget[4] have remarked—there seems sufficient probability in those views to justify the received use of the term "*protein compounds*," in speaking of the class, including fibrin, albumen, and others, to which the name of "*albuminous compounds*" was formerly applied.

2. *Globulin*.—The globulin of Berzelius consists of the envelopes of the blood corpuscles, and of the part of their contents that remains after the extraction of the hæmatosin. The two constitute *hæmatoglobulin*. M. Lecanu regards globulin as identical with albumen; according to Mulder, it belongs to the combinations of protein. Simon terms

[1] Scherer, Chemisch-physiologische Untersuchungen, Annalen der Chemie, &c., Oct. 1841, cited in Graham's Chemistry, Amer. edit., p. 692, Philad., 1843.

[2] Principles of Human Physiology, 2d edit., p. 479, Philad., 1845.

[3] Scherer, in Canstatt und Eisenmann's Jahresbericht über die Fortschritte in der Biologie im Jahre, 1847, s. 82. Erlangen, 1848.

[4] Manual of Physiology, Amer. edit., p. 24, Philad, 1849.

it *blood casein*, and Henle[1] thinks it probable, that it is in reality only albumen with the membranes of the blood corpuscles. Berzelius considers the crystalline lens to be composed of the same substance.

3. *Pepsin.*—This substance, to which Eberle gave the name, was discovered by Schwann. It seems to be a modification of protein, but has not been much examined. It is contained in the gastric juice; and its physiological properties will be described under the head of DIGESTION. It greatly resembles albumen; coagulates by heat and alcohol; and loses its solvent virtues. It is best procured by digesting portions of the mucous membrane of the stomach in cold water, after they have been macerated for some time in water at a temperature between 80° and 100° of Fahrenheit. The warm water dissolves various substances as well as some of the pepsin; but the cold water takes up little more than the pepsin, which is obtained by evaporating the cold solution in the form of a grayish-brown viscid fluid. The addition of alcohol throws down the pepsin in grayish-white flocculi; and one part of the principle thus prepared, when dissolved in even 60,000 parts of water, will digest meat and other alimentary substances. Liebig doubts the existence of pepsin as a distinct compound. According to him—as explained hereafter—the solvent power of the gastric juice is owing to the gradual decomposition of a matter dissolved from the lining membrane of the stomach, aided by oxygen introduced into the saliva.

4. *Gelatin.*—This is the chief constituent of cellular tissue, skin, tendons, ligaments, and cartilages. The membranes and bones also contain a large quantity of it. It is obtained by boiling these substances for some time in water; clarifying the concentrated solution; allowing it to cool, and drying the substance, thus obtained, in the air. In this state it is called *glue;* in a more liquid form, *jelly*. Gelatin dissolves readily in hot water; is soluble in acids and alkalies; insoluble in alcohol, ether, and in fixed and volatile oils. Alcohol precipitates it from its solution in water. It is not a compound of protein: hence it has been concluded, that it cannot yield albumen, fibrin, or casein; and, therefore, that blood cannot be formed of it. The animal system, it has been maintained, can convert one form of protein into another, but cannot form protein from compounds that do not contain it. This deduction—as stated hereafter—is probably too hasty. It is admitted, that gelatin may be produced from fibrin and albumen; since, in animals that are fed on these alone, the nutrition of the gelatinous tissues does not seem to be impaired; and it is as easy to conceive that gelatin may go to the formation of the proteinaceous tissues.

Gelatin, nearly in a pure state, forms the air-bag of different fishes, and is well known under the name of *isinglass*. It is used extensively in the arts, on account of its adhesive quality, under the forms of *glue* and *size*. What is called *portable soup* is dried jelly, seasoned with various spices.

5. *Chondrin.*—This was first discovered by J. Müller. It is obtained by boiling the cornea, the permanent cartilages, and the bones before ossification. It is a variety of gelatin.

[1] Op. cit., p. 53.

6. *Osmazome.*—This is the *matière extractive du bouillon, extractive, and saponaceous extract of meat.*—When flesh, cut into small fragments, is macerated in successive portions of cold water, the albumen, osmazome, and salts are dissolved; and, on boiling the solution, the albumen is coagulated. From the liquid remaining, the osmazome may be procured in a separate state, by evaporating to the consistence of an extract, and treating with cold alcohol. This substance is of a reddish-brown colour; and is distinguished from the other animal principles by solubility in water and alcohol—whether cold or at the boiling point—and by not forming a jelly when its solution is concentrated by evaporation.

Osmazome exists in the muscles of animals, the blood, and the brain. It gives the peculiar flavour of meat to soups; and, according to Fourcroy, the brown crust of roast meat consists of it.

Kreatin and *Kreatinin* are two principles which were formerly included among the extractive or ill-defined matters of muscular tissue. They have been investigated by Liebig,[1] who discovered them also in urine. They appear to be like urea, mere products of the decomposition of muscle.

7. *Mucus.*—This term has been applied to various substances; and hence the discordant characters ascribed to it. Applying it to the fluid secreted by mucous surfaces, it varies somewhat according to the source whence it is derived. Its leading characters may be exemplified in that derived from the nostrils, which has the following properties. It is insoluble in alcohol and water, but imbibes a little of the latter, and becomes transparent; it is neither coagulated by heat, nor rendered horny; but is coagulated by tannic acid.

Mucus, in a liquid state, serves as a protecting covering to different parts. Hence it varies somewhat in its characters, according to the office it has to fulfil. When inspissated, it forms, according to some, the minute scales that are detached from the surface of the body by friction, corns, and the thick layers of the soles of the feet, nails, and horny parts; and it is contained in considerable quantity in hair, wool, feathers, scales of fishes, &c.

8. *Urea.*—This proximate principle exists in the urine of the mammalia when they are in a state of health. In human urine it is less abundant after a meal, and it may nearly disappear in diabetes, and affections of the liver. It is obtained by evaporating urine to the consistence of syrup. The syrup is then treated with four parts of alcohol, which are afterwards volatilized by heating the alcoholic extract. The mass that remains is dissolved in water, or rather in alcohol, and crystallized.

The purest urea that has been obtained assumes the shape of acicular prisms similar to those of the muriate of strontian. It is colourless, devoid of smell, or of action on blue vegetable colours, transparent, and somewhat hard. Its taste is cool, slightly sharp, and its specific gravity is greater than that of water.

Urea is supposed by Dr. Prout to be chiefly derived from the de-

[1] Chemistry of Food, London, 1847.

composition of the gelatinous tissues; but, as Dr. Carpenter has remarked,[1] there seems to be no valid reason thus to limit the mode of its production.

9. *Uric* or *lithic acid.*—This acid is found in the urine of man, birds, serpents, tortoises, crocodiles, lizards; in the excrements of the silk-worm, and very frequently in urinary calculi. It is obtained by dissolving any urinary calculus which contains it, or the sediment of human urine, in warm liquid potassa, and precipitating the uric acid by the chlorohydric. Pure uric acid is white, tasteless, and inodorous. It is insoluble in alcohol, and is dissolved very sparingly by cold or hot water, requiring about 10,000 times its weight of that fluid, at 60° of Fahrenheit, for solution. According to Dr. Prout, this acid is not free, but is commonly combined with ammonia; the reddening of litmus paper being not altogether owing to it, but to the super-phosphate of ammonia, which is likewise present in urine.

In the herbivora, this acid is replaced by the hippuric. *Xanthic acid*, found by Marcet in urinary calculi, seems to have been uric acid.

10. *Red colouring principles of the blood.*—It has been already observed that Engelhart and Rose, German chemists, had detected iron in the red corpuscles of the blood, but had not found it in the other principles of that fluid. It has been considered probable, therefore, that it has something to do with the colour. Engelhart's experiments did not, however, determine the manner in which it acts, nor in what state it exists in the blood. The sulphocyanic acid which is found in the saliva, forms, with peroxide of iron, a colour exactly like that of venous blood; and it is possible, that the colouring matter may be a sulphocyanate of iron.

To obtain the red colouring matter, *hæmatin* or *hæmatosin*, allow the crassamentum or clot, cut into thin pieces, to drain as much as possible on bibulous paper, triturating it with water, and then evaporating the solution at a temperature not exceeding 122° of Fahrenheit. When thus prepared, the colouring particles are no longer of a bright red colour, and their nature is somewhat modified, in consequence of which they are insoluble in water. When half dried, they form a brownish-red, granular, friable mass; and, when completely dried at a temperature between 167° and 190°, the mass is tough, hard, and brilliant. The mode in which the hæmatosin is concerned in the coloration of the blood, will be inquired into under the head of RESPIRATION.

A brown colouring matter, *hæmaphæin*, and a blue colouring matter, *hæmacyanin*, have been described. The former, however, it has been suggested, is nothing more than hæmatin modified by an alkali; and Simon[2] never succeeded in detecting the latter.

11. *Yellow colouring principle of the bile;—cholepyrrhin* of Berzelius, *biliphæin* of Simon.—This substance is present in the bile of nearly all animals. It enters into the composition of almost all gall-stones, and is deposited in the gall-bladder under the form of magma.

[1] Human Physiology, § 673, Lond. 1842.

[2] Op. cit., p. 42.

It is solid; pulverulent; when dry, insipid, inodorous, and heavier than water. When decomposed by heat, it yields carbonate of ammonia, charcoal, &c. It is insoluble in water, alcohol, and the oils; but soluble in alkalies. On the gradual addition of nitric acid to a fluid, which contains this substance in solution, a very characteristic series of tints is evolved. The fluid becomes first blue, then green, afterwards violet and red, and ultimately assumes a yellow or yellowish-brown colour.

On adding an acid to a solution of biliphæin, a precipitation of green flocculi takes place: these possess all the properties of chlorophyll, or the green colouring matter of leaves. In this state it is termed *biliverdin* by Berzelius; and is a product of the metamorphosis of biliphæin.[1]

These are the chief nitrogenized organic elements.

b. *Organic Elements that do not contain Nitrogen.*

1. *Olein* and *Stearin.*—Fixed oils and fats are not pure proximate principles, as was at one time supposed. They were long presumed to consist of two substances, one of which is solid at the ordinary temperature of the atmosphere, and the other fluid: the former of these was called *Stearin*, from στεαρ, suet; the latter *Elaïn* or *Oleïn*, from ελαιον, oil. Stearin is the chief ingredient of vegetable and animal suet; of fat and butter; and is found, although in small quantity, in fixed oils. In suety bodies, it is the cause of their solidity. Elain and stearin may be separated from each other by exposing fixed oil to a low temperature; and pressing it, when congealed, between folds of bibulous paper. The stearin is thus obtained in a separate form; and by pressing the bibulous paper under water, an oily matter is procured, which is elain in a state of purity. Modern chemistry has shown, however, that fat contained in the cells of adipose tissue is composed of a base termed *glycerin*—itself hydrated oxide of glyceryl—with *stearic* and *margaric acids*. Stearin is a *bi-stearate of glycerin:*—olein, or elain, an *oleate of glycerin.*

2. *Fatty matter of the Brain and Nerves.*—Vauquelin[2] found two varieties of fatty matter in the brain,—the one white, the other red, the properties of which have not been fully investigated. Both give rise to phosphoric acid by calcination, without there being any evidence of an acid, or phosphate in their composition. They may be obtained by repeatedly boiling the cerebral substance in alcohol; filtering each time; mixing the various liquors, and suffering them to cool:—a lamellated substance is deposited, which is the *white fatty matter.* By evaporating the alcohol, which still contains red fatty matter and osmazome, to the consistence of *bouillie;* and exposing this, when cold, to the action of alcohol, the osmazome is entirely dissolved, whilst the alcohol takes up scarcely any *red fatty matter.*

3. *Acetic acid.*—This acid exists in a very sensible manner in sweat, urine, and milk—even when entirely sweet. It, or lactic acid, is formed in the stomach in indigestion; was found by the author and his late friend, Professor Emmet, contained in the gastric secretions in health,

[1] Simon, op. cit., p. 44.

[2] Annales de Chim., lxxxi. 37.

and is one of the constant products of the putrid fermentation of animal or vegetable substances. It is the most prevalent of the vegetable acids, and most easily formed artificially.

4. *Oxalic acid.*—This acid,—which exists extensively in the vegetable kingdom, but always united with lime, potassa, soda, or oxide of iron,—is only found, combined with lime, as an animal constituent in certain urinary calculi.

5. *Benzoic acid.*—This acid, found in many individuals of the vegetable kingdom, is likewise met with in the urine of the horse, cow, camel, and rhinoceros; and sometimes in that of man, especially of children. When benzoic acid is swallowed, hippuric acid is observed in the urine; and it was supposed by Mr. A. Ure and others, that this was owing to the conversion of uric acid into hippuric; and as the hippurates are more soluble, it was suggested by him, that benzoic acid might be advantageously exhibited in lithuria, and in cases of gouty depositions of lithate of soda. It has been found, however, by Drs. Keller and Garrod,[1] and by Professor Booth, and Mr. Boyé, of Philadelphia,[2] that the administration of benzoic acid exerts no influence on the amount of uric acid in the urine.

6. *Lactic acid.*—*Acid of milk* is met with in blood, gastric juice, urine, milk, marrow, and also in muscular flesh. At times it is in a free state, but is usually united with alkalies. However much it may be concentrated, it does not crystallize, but remains under the form of syrup or extract. When cold it is tasteless, but when heated has a sharp acid taste. According to Dr. Prout, this acid, like urea, results from the decomposition of the gelatinous parts of the system; according to Berzelius, however, it is a general product of the spontaneous decomposition of animal matters within the body. Liebig[3] formerly denied, that any lactic acid is formed in the stomach in health; and affirmed, that the property possessed by many substances, such as starch, and the varieties of sugar, by contact with animal matters in a state of decomposition, of passing into lactic acid, had induced physiologists too hastily to assume the fact of the production of lactic acid during healthy digestion:—yet he now admits its presence.

7. *Sugar of milk.*—This substance, which is so called because it has a saccharine taste, and exists chiefly, if not solely, in milk, differs from ordinary sugar in not fermenting. It is obtained by evaporating whey, formed during the making of cheese, to the consistence of honey; allowing the mass to cool; dissolving; clarifying and crystallizing. It commonly crystallizes in regular parallelopipedons, terminated by pyramids with four faces. It is white; semitransparent; hard, and of a slightly saccharine taste.

8. *Sugar of diabetes.*—In *diabetes mellitus*, the urine, which is often passed in enormous quantity, contains, at the expense of the economy, a large amount of peculiar saccharine matter, which, when properly purified, appears identical in properties and composition with vegetable

[1] Liebig's Animal Chemistry, p. 316.

[2] Proceedings of the American Philosophical Society at the Centennial Celebration in Phila., May, 1843, and Transactions of the A. P. Society, vol. ix. pt. 2, Philad., 1845.

[3] Op. cit., p. 107.

sugar, and approaches nearer to the sugar of grapes—*glucose*—than to that of the cane. It is obtained in an irregularly crystalline mass, by evaporating diabetic urine to the consistence of syrup, and keeping it in a warm place for several days. It is purified by washing in cold, or—at the most—gently heated alcohol, till the liquor comes off colourless; and then dissolving it in hot alcohol. By repeated crystallization it is thus rendered pure.[1] In the notes of two cases of diabetes mellitus now before the author, it appears, that sixteen ounces of the urine of one patient, of the specific gravity of 1·034, afforded a straw-coloured extract, which, when cold and consolidated, weighed one ounce and five drachms. The same quantity of the urine of the other patient, specific gravity 1·040, yielded one ounce and seven drachms. Neither extract appeared to contain urea when nitric acid was added; but when a portion was dissolved in water, and subjected to a temperature of 212°, traces of ammonia were manifested on the vapour being presented to the fumes of chlorohydric acid. From this a conclusion was drawn, that urea was present, as it is the only known animal matter decomposed by the heat of boiling water. In a little more than a month, the subject of the latter case passed about four hundred and eighty pints of urine, or about seventy-five pounds troy of diabetic sugar!

9. *Bilin* or *Picromel.*—M. Thénard[2] discovered this principle in the bile of the ox, sheep, dog, cat, and several birds; Chevalier, in that of man. To obtain it, the acetate of lead of commerce must be added to bile until there is no longer any precipitate. By this means, the yellow matter of the bile and the whole of the fatty matter are thrown down, united with the oxide of lead; the phosphoric acid of the phosphate of soda, and the sulphuric acid of the sulphate of soda, are likewise precipitated. The picromel may then be thrown down from the filtered liquor by the subacetate of lead. The precipitate, which is a combination of picromel with oxide of lead, must now be washed and dissolved in acetic acid. Through this solution, sulphuretted hydrogen is passed to separate the lead; the solution is then filtered, and the acetic acid driven off by evaporation.

Pure picromel is devoid of colour, and has the same appearance and consistence as thick turpentine. Its taste is at first acrid and bitter, but afterwards sweet. Its smell is nauseous, and specific gravity greater than that of water. When digested with resin of bile, a portion of the latter is dissolved, and a solution obtained, which has a bitter and a sweet taste, and yields a precipitate with the subacetate of lead and the stronger acids. This is the compound that causes the peculiar taste of the bile.

10. *Cholesterin.*—This is a constituent principle of the blood, bile, medullary neurine, and *vernix caseosa.* It is often precipitated from bile in a crystalline state; and forms of itself concretions which have an evidently laminated texture. It has been very frequently met with in morbid secretions and tissues; in the fluid of dropsies; in that of cysts and hydatids; and in medullary fungus and other tumours. At

[1] Prout, Medico-Chirurg. Transact., viii. 538.
[2] Mémoir. d'Arcueil, i. 23, and Traité de Chimie, tom. iii.

times, it is dissolved; at others, swims upon the fluid in brilliant plates, or forms solid masses. It is obtained from biliary calculi by boiling in water, and dissolving them afterwards in boiling alcohol. On cooling, crystals of cholesterin separate.

These inorganic and organic elements—with others of less moment discovered by modern chemists—variously combined and modified by the vital force, constitute the different parts of the animal fabric. Chemistry, in its present improved condition, enables us to separate them, and to investigate their properties; but all the information we derive from this source relates to bodies, that have been influenced by the vital force, but are no longer so; and in the constant mutations that occur in the system whilst life exists, and under its controlling agency, the same textures might exhibit very different chemical characteristics, could our researches be directed to them under those circumstances. Whenever, therefore, the physiologist has to apply chemical elucidations to operations of the living machine, he must recollect, that all his analogies are drawn from dead matter, which differs so widely from the living as to suggest the necessity of a wise and discriminating caution.

The components of the animal body are invariably found under two forms—*solids* and *fluids*. Both are met with in every animal, the former being derived from the latter; for, from the blood every part of the body is separated; yet they are mutually dependent, for every liquid is contained in a solid. The blood itself circulates in solid vessels. Both, too, possess an analogous composition; are in constant motion, and incessantly converted from one into the other. Every animal consists of a union of the two; and this union is indispensable to life. Yet certain vague notions with regard to their relative preponderance in the economy, and to their agency in the production of disease, have led to discordant doctrines of pathology,—the *solidists* believing, that the cause of most affections is resident in the solids; the *humorists*, that we are to look for it in the fluids. In this, as in similar cases, the mean will lead to the most satisfactory result. The causes of disease ought not to be sought in the one or the other exclusively.

c. *Of the Solid Parts of the Human Body.*

A *solid* is a body whose particles adhere to each other, so that they do not separate by their own weight; but require the agency of some extraneous force to effect the disjunction. Anatomists reduce all the solids of the human body to twelve varieties;—*bone, cartilage, muscle, ligament, vessel, nerve, ganglion, follicle, gland, membrane, areolar membrane*, and *viscus*.

1. *Bone* is the hardest of the solids. It forms the skeleton; the levers for the various muscles to act upon; and serves for the protection of important organs.

2. *Cartilage* is of a white colour, formed of very elastic tissue; covering the articular extremities of bone to facilitate their movements; sometimes added to bones to prolong them, as in the case of the ribs;

at others, placed within the articulations to act as elastic cushions; and, in the fœtus, forming a substitute for bone. Hence, cartilages are divided into *articular* or *incrusting*, *cartilages of prolongation*, *interarticular cartilages*, and *cartilages of ossification.*

3. *Muscles* constitute the flesh of animals. They consist of fasciculi of red and contractile fibres, extending generally from one bone to another; and are the agents of all movements.

4. *Ligaments* are tough; difficult to tear; and, under the form of cords or membranes, serve to connect different parts with each other, particularly bones and muscles; hence their division, by some anatomists, into *ligaments of bones*—as the ligaments of the joints; and *ligaments of muscles*,—as the tendons and aponeuroses.

5. *Vessels* are solids, having the form of canals, in which the fluids circulate. They are called—according to the fluid they convey—*sanguineous* (*arterial* and *venous*), *chyliferous*, *lymphatic*, &c.

6. *Nerves* are cords, consisting of numerous tubular fasciculi. These are connected with the brain, spinal marrow, or great sympathetic. They are the organs by which impressions are conveyed to the nervous centres, and by which each part is endowed with vitality. There are three great divisions of the nerves,—the *cerebro-spinal*, *true spinal*, and *organic.*

7. *Ganglions* are solid knots in the course of a nerve which seem to be formed of an inextricable interlacing of nervous filaments. The term is likewise applied, by many modern anatomists, to similar interlacings of the ramifications of lymphatic vessels. *Ganglions* may, consequently, either be *nervous* or *vascular;* and the latter, again, may be divided into *chyliferous* or *lymphatic*, according to the kind of vessel on which they appear. Chaussier, a distinguished anatomist and physiologist, has given the name *glandiform ganglions* to certain organs whose nature and functions are unknown, but which appear to be concerned in lymphosis,—as the thymus gland, the thyroid gland, &c.

8. *Follicles* or *crypts* are secretory organs, shaped—when simple—like membranous ampullæ or vesicles, formed by an inversion of the outer membranes of the body—the skin and mucous surfaces—and secreting a fluid intended to lubricate them. They are often divided into the *simple* or *isolated;* the *conglomerate;* and the *compound*, according to their size, or the manner in which they are grouped and united together.

9. *Glands* are secretory organs not differing essentially from the last. Their organization is more complex; and the fluid, after secretion, is poured out by means of one or more excretory ducts.

10. *Membrane.*—This is one of the most extensive and important of the substances formed by the areolar tissue. It is spread out in the shape of a web; and, in man, serves to line cavities and reservoirs; and to form, support, and envelope organs.

Bichat divides membranes into two kinds, *simple* and *compound*, according as they are formed of one or more layers.

Simple membranes are of three kinds, *serous*, *mucous*, and *fibrous.*

1*st.* *Serous membranes* constitute all the sacs or shut cavities of the body,—those of the chest and abdomen, for example.

2*dly*. *Mucous membranes* line all the outlets of the body,—the air-passages, alimentary canal, urinary and genital organs, &c.

3*dly*. *Fibrous membranes* form tendon, aponeurosis, ligament, &c.

Compound membranes are formed by the union of the simple, and are divided into *fibro-serous*, as the pericardium; *sero-mucous*, as the gall-bladder, at its lower part; and *fibro-mucous*, as the ureter.

11. *Areolar*, *cellular* or *laminated tissue*—to be described presently—is a sort of spongy or areolar structure, which forms the framework of the solids; fills up the spaces between them, and serves at once as a bond of union and separation.

12. A *viscus* is the most complex solid of the body; not only as regards intimate organization, but use. This name is given to organs contained in the splanchnic cavities,—brain, thorax, and abdomen,—and hence the viscera are termed *cerebral*, *thoracic*, and *abdominal*.

Every animal solid is either *amorphous* or *fibrous;* that is, it is either without apparent arrangement, like jelly; or is disposed in minute threads, called *fibres*. The disposition of these threads, in different structures, is various. Sometimes, they retain the form of threads; at others, they have that of laminæ, lamellæ, or plates. Accordingly, when we examine any animal solid, where the organization is perceptible, it is found to be either amorphous, or fibrous and laminated.

This circumstance led the ancients to endeavour to discover an *elementary fibre* or *filament*, from which the various organs might be formed. Haller[1] embraced the idea, and endeavoured to unravel every texture to this ultimate element,—which, he conceived, is to the physiologist what the line is to the geometer; and, as all figures can be constructed from the line, so every tissue and organ of the body may be built up from the *filament*. Haller, however, admitted that this elementary fibre is not capable of demonstration, and that it is visible only to the "mind's eye,"—"*invisibilis ea fibra, quam solâ mentis acie adtingimus.*" It must be regarded, indeed, as a pure abstraction; for, as different animal substances in the mass have different proportions of carbon, hydrogen, oxygen, and nitrogen, it is fair to conclude that the elementary fibre must equally differ in the different substances.

The ancients believed that the first product of the elementary fibre was areolar tissue; and that this tissue forms every organ of the body,—the difference in the appearance of the organs arising from the different degrees of condensation of its laminæ. Anatomists, however, have been unable to reduce all animal solids to areolar tissue only.

In the upper classes of animals, three *primary fibres* or *tissues* or anatomical elements are usually admitted,—the *areolar*, *cellular* or *laminated;* the *muscular;* and the *nervous*, *pulpy* or *medullary*.

1. The *areolar*, *cellular*, *mucous*, *filamentous* or *laminated fibre* or *tissue* is the most simple and abundant of animal solids. It exists in every organized being; and is an element of every solid. In the enamel of the teeth only it has not been detected. It is formed of an assemblage of thin laminæ, of delicate, whitish, extensible filaments,

[1] Elementa Physiologiæ, vol. i. lib. i. sect. i. p. 7, Lausan., 1757.

interlacing and leaving between each other areolæ or cells. These filaments—although possessed, like every other living tissue, of contractility or the power of feeling an appropriate irritant and of moving responsive to such irritant—do not move perceptibly under the influence of mechanical or chemical stimuli. They are mainly composed of concrete gelatin.—The great bulk of animal solids consists of areolar tissue, arranged as membrane.

2. *Muscular fibre* or *tissue* is a substance of peculiar nature; arranged in fibres of extreme delicacy. The fibres are linear, soft, grayish or reddish, and manifestly possessed of contractility or irritability; that is, they move very perceptibly under the influence of mechanical or chemical stimuli. They are composed, essentially, of fibrin. Their histology will be described hereafter.

Muscular fibres, which are arranged in the form of membranous expansions or muscular coats, differ from proper muscles chiefly in the mechanical disposition of the fibres. The physical and chemical characters of both are identical. The fibres, instead of being collected into fasciculi, are in layers, and, instead of being parallel, interlace. This tissue does not exist in the zoophyte.

3. *Nervous*, *pulpy*, or *medullary fibre* or *tissue*, which will be referred to hereafter, is much less distributed than the preceding. It is of a pulpy consistence; is composed essentially of albumen united to a phosphuretted fatty matter; and is the organ for receiving and transmitting impressions to and from the nervous centres. Of it, brain, cerebellum, medulla spinalis, nerves and their ganglia are composed.

Professor Chaussier[1] added another primary fibre or tissue,—the *albugineous*. It is white; satiny; resisting; of a gelatinous nature; and constitutes tendons and tendinous structures. Chaussier is, perhaps, the only anatomist that admits this tissue. Others properly regard it as a condensed variety of the areolar.

These various fibres or tissues, by uniting differently, constitute the first order of solids; and these, again, by union, give rise to *compound solids*, from which the different organs are formed. A bone, for example, is a compound of various tissues; *osseous* in its body; *medullary* in its interior; and *cartilaginous* at its extremities.

Bichat[2] was the first anatomist who possessed clear views regarding the constituent tissues of the animal frame; and whatever merit may accrue to after anatomists and physiologists, he is entitled to the credit of having pointed out the path, and facilitated the labours of the anatomical analyst.

The term texture can only apply to solids; but inasmuch as there are in suspension in certain fluids, as the blood, chyle and lymph, solid corpuscles of determinate form and organic properties, and which are not mere products or secretions of a particular organ, or confined to a particular part, such corpuscles have been looked upon as organized constituents of the body, and therefore considered along with the solid tissues; and, accordingly, the textures and other organized constituents have been enumerated as follows:[3]

[1] Table Synoptique des Solides Organiques. [2] Anatomie Gén., Paris, 1801, tom. i.
[3] Quain and Sharpey, Human Anatomy, Amer. edit., by Dr. Leidy, i. 39, Philad., 1849.

The blood, chyle and lymph.
Epidermic tissue, including epithelium, cuticle, nails, and hairs.
Pigment.
Adipose tissue.
Cellular (areolar) tissue.
Fibrous tissue.
Elastic tissue.
Cartilage and its varieties.
Bone or osseous tissue.
Muscular tissue.
Nervous tissue.
Bloodvessels.
Absorbent vessels and glands.
Serous and synovial membranes.
Mucous membranes.
Skin.
Secreting glands.

Under the idea, now entertained, that all organized tissues are essentially composed of cells having plastic or formative powers, with an intercellular substance or blastema, the tissues have been thus arranged by Schwann,[1] the great author of the cell doctrine.

1. Isolated, independent cells. To this class the cells in fluids pre-eminently belong:—lymph globules; blood corpuscles.

2. Independent cells united into continuous tissues; such as the horny tissues and the crystalline lens.

3. Cells in which only the cell walls have coalesced,—cartilage, bone, and the *substantia propria* (ivory) of the teeth.

4. Fibre cells,—cellular (areolar), fibrous and elastic tissue.

5. Cells in which both the cell walls and cell cavities have coalesced, —muscle, nerve and capillary vessels.

Dr. Allen Thomson[2] has proposed the following tabular view, which —he remarks—may be adopted in preference to the foregoing as combining similar theoretical considerations, with a more immediate reference to the actual form of the prevailing structural elements in the different tissues. He properly adds, however, that this classification is open—as he might have said every arrangement must be—to several objections; inasmuch as it brings together, under the same head, some parts endowed with different functions; and separates some textures whose functions are closely related; and it does not point out sufficiently the usual degree of complexity of the several textures.

Some part of it, moreover, is founded on theoretical considerations not yet fully established; and the distinctions on which it rests are based on a structural analysis of various extent in the different textures. On the whole, however, it is a sufficient exponent of the existing state of belief on the subject.

I. Organized textures in which the cellular form of the constituent elements is apparent; not unfrequently also presenting granules of molecular deposition.

1. Rounded simple cells, floating loose in fluid, *Blood*, *Lymph*, *Chyle* and *Milk corpuscles*, *&c.*

2. Simple cells massed together, either preserving their cellular form, and without other parts intervening, or altered in form and mixed with

[1] Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants. Sydenham Society's edit., by Henry Smith, p. 66, London, 1847.
[2] Outlines of Physiology for the Use of Students, pt. i. p. 68, Edinb., 1848.

other solid elements:—*Pigment*, *Fat*, *Cuticle*, *Horny textures*, *Epithelium*, *Crystalline lens*, *Cartilage*.

3. Simple cells, or their contents, altered in form:—*Ciliated texture*, *Spermatozoa*.

4. Compound cells, separate or mixed with other textures:—*Ovum*, *Ganglionic corpuscles*.

II. Textures exhibiting a simply fibrous structure.

1. Filamentous (areolar) texture; formerly *Cellular texture*.

2. Fibrous textures:—*Tendon*, *Ligament*, *Fibrous membranes*, *Fibrous plates*.

3. Elastic fibrous texture.

III. Textures exhibiting a tubular structure.

1. Containing moving fluids:—*Bloodvessels* and *Absorbent vessels*.

2. Containing muscular substance:—*Striated* and *non-striated muscular fibre*.

3. Containing nervous matter:—*Primitive nerve tubes*.

IV. Textures exhibiting a membranous structure.

1. Principally filamentous:—*Serous* and *Synovial membranes*.

2. Filamentous and vascular:—*Mucous membranes; True skin*.

3. Membrane and cells:—*Glands*.

4. Membrane and Bloodvessels, &c.:—*Lungs*.

In combining to form the different structures, the solids are arranged in various ways. Of these, the chief are in filaments or elementary fibres, tissues, organs, apparatuses, and systems. A *filament* is the elementary solid. A *fibre* consists of a number of filaments united together. Occasionally, this is called a *tissue*:—the term *tissue* usually, however, means a particular arrangement of fibres. An *organ* is a compound of several tissues. An *apparatus* is an assemblage of organs, concurring to the same end:—the *digestive apparatus* consists of the organs of mastication, insalivation, and deglutition, the stomach, duodenum, pancreas, liver, &c. These may be, and are, of very dissimilar character, both as regards their structure and functions; but, if they concur in the same object, they form an *apparatus*. A *system*, on the other hand, is an assemblage of organs, all of which possess the same or an analogous structure. Thus, all the muscles of the body have a common structure and function; and form, in the aggregate, the *muscular system*. All the vessels of the body, and all the nerves, for like reasons, constitute, respectively, the *vascular*, and *nervous systems*.

d. *Of the Fluids of the Human Body.*

The positive quantity or proportion of the fluids in the human body does not admit of appreciation, as it must vary at different periods, and under different circumstances. The younger the animal, the greater is its preponderance. When we first see the embryo, it appears to be almost wholly fluid. As it becomes gradually developed, the proportion of solid parts increases, until the adult age; after which it becomes less and less in the progress of life. During the whole of existence, too, the quantity of fluids in the body fluctuates. At times, there is plethora

or unusual fulness of blood-vessels; at others, the blood is less in quantity.

Experiments have been made for the purpose of ascertaining the relative proportion of fluids to solids. M. Richerand says, that they are in the ratio of six to one; M. Chaussier, of nine to one. The latter professor put a dead body, weighing one hundred and twenty pounds, into a heated oven, and dried it. After desiccation, it was found to be reduced to twelve pounds. It is probable, however, that some of the more solid portions were driven off by the heat employed; and hence, that the estimated proportion of fluids was too high. On this account, M. Bérard[1] thinks, that instead of estimating the proportion of liquids at nine-tenths, it would be better to take the mean result of experiments by M. Chevreul, who performed the desiccation *in vacuo* and with a very moderate heat. This would give the proportion of water in the human body about 6·667 parts in the 10·000.

In the Egyptian mummies, which are completely deprived of fluid, the solids are extremely light, not weighing more than seven pounds; but as we are ignorant of the original weight of the body, we cannot arrive at any approximation. The dead bodies found in the arid sands of Arabia, as well as the dried preparations of the anatomical theatre, afford additional instances of reduction by desiccation. To a less extent, we have the same thing exhibited in the excessive diminution in weight that occurs in disease, and occasionally in those who are apparently in health. Not many years ago, an *Anatomie vivante* was exhibited in London to the gaze of the curious and scientific, whose weight was not more than eighty pounds. Yet the ordinary functions were carried on, apparently unmodified. In the year 1830, a still more wonderful phenomenon was shown. A man, named Calvin Edson, forty-two years old, five feet two inches high, weighed but sixty pounds. His weight had formerly been one hundred and thirty-five pounds. For sixteen years previously, he had been gradually losing flesh, without any apparent disease, having enjoyed perfect health and appetite, and eating, drinking, and sleeping as well as any one. He was properly called the "*living skeleton.*" It was stated in the public journals[2] that Dr. Edson, a brother of Calvin, was to all appearance entirely destitute of flesh. He was, in 1847, forty-two years old; of ordinary height—five feet six inches, and yet weighed only forty-nine pounds. He retained all his faculties apparently in full vigour. We have it also, on the authority of Captain Riley,[3] that after protracted sufferings in Africa, he was reduced from two hundred and forty pounds to below ninety [?].

The fluids are variously contained; sometimes in vessels—as the blood and lymph; at others, in cavities—as the fluids secreted by the pleura, peritoneum, arachnoid coat of the brain, &c.: others are in minute areolæ—as the fluid of the areolar membrane; whilst others, again, are intimately combined with the solids. They differ likewise in density,—some existing in the state of halitus or vapour; others

[1] Cours de Physiologie, p. 200, Paris, 1848.
[2] Philadelphia Public Ledger, Feb. 2, 1847.
[3] Narrative of the Loss of the American Brig Commerce, &c., p. 302. New York, 1817.

being very thin and aqueous—as the fluid of the serous membranes; and others of more consistence—as the secretion of the mucous membranes, animal oils, &c.

The physical and chemical properties of the fluids will engage attention when they fall individually under consideration; and we shall find that one of them at least—the blood—exhibits certain phenomena analogous to those of the living solid.

The fluids have been differently classed, according to the particular views that have, from time to time, prevailed in the schools. The ancients referred them all to four,—blood, bile, phlegm or pituita, and atrabilis; each of which was conceived to abound in one of the four ages, seasons, climates, or temperaments. Blood predominated in youth, in the spring, in cold mountainous regions, and in the sanguine or inflammatory temperament. Pituita or phlegm had the mastery in old age, in winter, in low and moist countries, and in the lymphatic temperament. Bile predominated in mature age, in summer, in hot climates, and in the bilious temperament; and atrabilis was the characteristic of middle age, of autumn, of equatorial climes, and of the melancholic temperament. This was their grand humoral system, which has vanished before a better observation of facts, and more improved methods of physical and metaphysical investigation. The atrabilis was a creature of the imagination; the pituitous condition is unintelligible to us; and the doctrine of the influence of the humours on the ages, temperaments, &c., irrational.

Subsequently, the humours were classed according to their physical and chemical properties: they were divided, for instance, into liquids, vapours, and gases; into acid, alkaline, and neutral; into thick and thin; into aqueous, mucilaginous, gelatinous, and oily; into saline, oily, saponaceous, mucous, albuminous, and fibrinous, &c. In more modern times, endeavours have been made to arrange them according to their uses in the economy into—1, *recrementitial fluids*, or those intended to be again absorbed; 2, *excrementitial*, those that have to be expelled from the body; and 3, those which participate in both purposes, and are hence termed *excremento-recrementitial*. Blumenbach[1] divided them into crude humours, blood, and secreted humours, a division which has been partly adopted by M. Adelon;[2] and Chaussier, whose anatomical arrangements and nomenclature have rendered him justly celebrated, reckoned five classes:—1, those produced by the act of digestion,—chyme and chyle; 2, the circulating fluids,—lymph and blood; 3, the perspired fluids; 4, the follicular; and 5, the glandular. This arrangement has been adopted by M. Magendie,[3] and, with slight modification, is perhaps as satisfactory as any that has been proposed. All these will have to engage attention under SECRETION.

e. *Physical Properties of the Tissues.*

The tissues of the body possess the physical properties of matter in

[1] Institutiones Physiologicæ, Sect. ii., § 4. Gotting., 1798.
[2] Physiologie de l'Homme, 2de édit., i. 124. Paris, 1829.
[3] Précis Elémentaire de Physiol., 2de édit., i. 20. Paris, 1825.

general. They are found to vary in consistence,—some being hard, and others soft; as well as in colour, transparency, &c. They have, also, physical properties, analogous, indeed, to what are met with in certain inorganic substances, but generally superior in degree. These are *flexibility*, *extensibility*, and *elasticity*, which are variously combined and modified in the different forms of animal matter, but exist to a greater or less extent in every tissue. *Elasticity* is only exerted under particular circumstances: when the part, for example, is put upon the stretch or compressed, the force of elasticity restores it to its primitive state, as soon as the distending or compressing cause is withdrawn. The tissues, in which elasticity is inherent, are so disposed through the body, as to be kept in a state of distension by the mechanical circumstances of situation; but, as soon as these circumstances are modified, elasticity comes into play, and produces shrinking of the substance. It is easy to see, that these circumstances, owing to the constant alteration in the relative situation of parts, must be ever varying. Elasticity is, therefore, constantly called into operation, and in many cases acts upon the tissues as a new power. The cartilages of the ribs, joints, &c., are in this manner valuable agents in particular functions.

We have other examples of the mode in which elasticity exhibits itself, when the contents of hollow parts are withdrawn, and whenever muscles are divided transversely. The gaping wound, produced by a cut across a shoulder of mutton, is familiar to all. Previous to the division, the force of elasticity is kept neutralized by the mechanical circumstances of situation,—or by the continuity of the parts; but as soon as this continuity is disturbed, in other words, as soon as the mechanical circumstances are altered, the force of elasticity is exerted, and produces recession of the edges. This property has been described under various names, *tone* or *tonicity*, *contractilité de tissu*, *contractilité par défaut d'extension*, &c.

The other properties, *flexibility* and *extensibility*, vary greatly according to the structure of parts. The tendons, which are composed of areolar tissue, exhibit very little extensibility; and this for wise purposes. They are the conductors of force developed by muscle, and were they to yield, it would be at the expense of the muscular efforts; but they possess great flexibility. The articular ligaments are very flexible, and somewhat more extensible. On the other hand, the fibrous or ligamentous structures, which are employed to support weights, or are antagonists to muscular action,—as the *ligamentum nuchæ*, which passes from the spine to the head of the quadruped,—are very extensible and elastic.

Another physical property, possessed by animal substances, is a kind of contractility, accompanied with sudden corrugation and curling. This effect, which Bichat terms *racornissement*, is produced by heat, and by chemical agents, especially the strong mineral acids. The property is exhibited by leather when thrown into the fire.

An effect, in some measure resembling this, is caused by the evaporation of the water that is united to animal substances. This constitutes what has been called the *hygrometric property* of animal mem-

branes.[1] It is characteristic of dry, membranous structures; all of which are found to contract, more or less, by the evaporation of moisture, and to expand again by its re-absorption; hence the employment of such substances as *hygrometers*. According to M. Chevreul,[2] many of the tissues are indebted for their physical properties to the water they contain, or with which they are imbibed. When deprived of this fluid, they become unfit for the purposes for which they are destined in life, and resume them as soon as they have recovered it.

A most important property possessed by the tissues of organized bodies is *imbibition;* a property to which attention has been chiefly directed of late years. If a liquid be put in contact with any organ or tissue, in process of time the liquid will be found to have passed into the areolæ of the organ or tissue, as it would enter the cells of a sponge. The length of time occupied in this imbibition will depend upon the nature of the liquid and the kind of tissue. Some parts of the body, as the serous membranes and small vessels, act as true sponges, absorbing with great promptitude; others resist imbibition for a considerable time,—as the epidermis.

Liquids penetrate equally from within to without: the process is then called *transudation*.

Some singular facts have been observed regarding the imbibition of fluids and gases. On filling membranous expansions, as the intestine of a chicken, with milk or some dense fluid, and immersing it in water, M. Dutrochet[3] observed, that the milk left the intestine, and the water entered it; hence he concluded, that whenever an organized cavity, containing a fluid, is immersed in another fluid, less dense than that which is in the cavity, there is a tendency in the cavity to expel the denser and absorb the rarer fluid. This M. Dutrochet termed *endosmose*, or "inward impulsion;" and he conceived it to be a new power, a "physico-organic or vital action." Subsequent experiments showed, that a reverse operation could take place. If the internal fluid was rarer than the external, the transmission occurred in the opposite direction. To this reverse process, he gave the name *exosmose*, or "outward impulsion." At times, the term endosmose is applied to the mutual action of two liquids when separated by a membrane;[4] at others, to the passage of the liquid, that permeates the membrane in greatest quantity.[5]

Soon after the appearance of M. Dutrochet's essay, the experiments were repeated, with some modifications, by Dr. Faust,[6] and by Dr.

[1] Roget, art. Physiology, in Supplement to Encyclopædia Britannica; and Outlines of Physiology, with an Appendix on Phrenology. First American edition, with notes by the author of this work, p. 73, Philad., 1839.

[2] Magendie, Précis Elémentaire de Physiologie, 2de édit., 1825, i. 13.

[3] Mém. pour servir à l'Histoire Anatom. et Physiol. des Animaux et des Végétaux, Paris, 1837; art. Endosmosis, in Cyclopædia of Anatomy and Physiology, part x. p. 98, June, 1837. See, also, Vierordt, art. Transudation und Endosmose, in Wagner's Handwörterbuch der Physiologie, s. 631, Braunschweig, 1848.

[4] Matteucci, Lectures on the Physical Phenomena of Living Beings; translated by Pereira, p. 45, Amer. edit., Philad., 1848.

[5] Poiseuille, Comptes Rendus, xix. 944, Paris, 1844.

[6] Amer. Journal of the Med. Sciences, vii. 23, Philad., 1830.

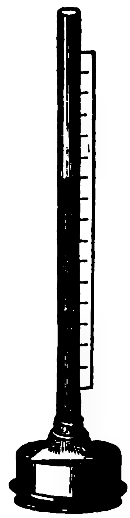
Togno,[1] of Philadelphia; and with like results. The fact of this imbibition and transudation was singular and impressive; and, with so enthusiastic an individual as M. Dutrochet, could not fail to give birth to numerous and novel conceptions. The energy of the action of both endosmose and exosmose is in proportion, he asserted, to the difference between the specific gravities of the two fluids; and, independently of their gravity, their chemical nature affects their power of transmission. These effects—he at once decided—must be owing to electricity. The cavities, in which the changes take place, he conceived to be like Leyden jars having their two surfaces charged with opposite electricities,—the ultimate effect or direction of the current being determined by the excess of the one over the other.

In an interesting and valuable communication by Dr. J. K. Mitchell,[2] of Philadelphia, "on the penetrativeness of fluids," many of the visionary speculations of M. Dutrochet are sensibly animadverted upon. It is there shown, that he had asserted, in the teeth of some of his most striking facts, that the current was from a less dense to a more dense fluid; and that it was from positive to negative, dependent not on an inherent power of filtration,—a power always the same when the same membrane is concerned,—but modified at pleasure by supposed electrical agencies. This view was subsequently abandoned by M. Dutrochet, in favour of the following principle. It is well known that porous bodies, as sugar, wood, or sponge, are capable of imbibing liquids, with which they are in contact. In such case the liquid is not merely introduced into the pores of the solid, as it would be into an empty space; but is forcibly absorbed, so that it will rise to a height considerably above its former level. This force is molecular, and is the same that we witness in the phenomena presented by the capillary tube, which affords us the simplest case of the insinuation of a liquid into a porous body. It cannot alone, however, cause the liquid to pass entirely through the body. If a capillary tube, capable of raising water to the height of six inches, be depressed, so that one inch only be above the surface, the water will rise to the top of the tube; but no part of it will escape. Even if the tube be inserted horizontally into the side of the vessel containing water, the water will only pass to the end of the tube. The same thing occurs when a liquid is placed in contact with one side of a porous membrane: it enters the pores; passes to the opposite side, and is there arrested. But if this membrane communicates with a second vessel containing a different liquid—as a saline solution, capable of mixing with the first, and affected to a different degree by capillary attraction—a new phenomenon will be presented. It will be found, that both liquids enter the pores, and pass through to the opposite side. They will not, however, be carried through with the same force: that which has the greatest power of capillary ascension, has the greatest affinity for the membrane, or will wet it more readily, —in other words, that which will rise the highest in a capillary tube, will pass through in greater quantity, and cause an accumulation of liquid on the opposite side. The action is well shown by the simple

[1] Amer. Journal of the Med. Sciences, iv. 73, Philad., 1829.
[2] Ibid., vii. 23, Philad., 1830.

instrument figured in the margin. It consists of a glass tube, the lower extremity of which, covered by bladder, is funnel-shaped. This M. Dutrochet termed an endosmometer. If an aqueous solution of either gum or sugar be poured into it, and the closed extremity be immersed in pure water, the water is found to pass continually into the tube by filtration through the membrane, so that the liquid will rise in the tube, and may even flow out at the upper aperture. At the same time, a portion of the mucilaginous or saccharine solution will escape from the tube through the bladder, and become mixed with the water, but the quantity will be much less than that of the water which entered.

Fig. 1.



Endosmometer.

The facts and arguments adduced by Dr. Mitchell clearly exhibit, that imbibition and transudation are dependent upon the penetrativeness of the liquid, and the penetrability of the membrane; that if two liquids, of different rates of penetrativeness, be placed on opposite sides of an animal membrane, "they will in time present the greater accumulation on the side of the less penetrant liquid, whether more or less dense; but will, finally, thoroughly, and uniformly mix on both sides; and at length, if any pressure exist on either side, yield to that, and pass to the other side."[1] In all such cases, there are both endosmose and exosmose—or double imbibition; in other words, a certain quantity of one fluid passes in, and a certain quantity of the other passes out.[2] As a general rule, imbibition takes place from the rarer to the denser medium; from pure water or dilute solutions towards those that are more concentrated. It would appear, again, that the stronger current is always from the medium which has the strongest affinity for the substance of the septum. It is well known, that in the case of a mixture of dilute alcohol covered over by a piece of bladder, the alcohol becomes concentrated, owing to the water—a denser fluid—passing more rapidly through the septum or bladder than the alcohol; but if the same mixture be tied over with elastic gum, the contrary effect will be produced—the alcohol escaping in greater quantity.[3] The general conditions of the phenomena of endosmose are:—*first*, that the two liquids shall have an affinity for the septum or interposed membrane; and, *secondly*, that they shall have an affinity for, and be miscible with, each other.

A portion of the communication of Dr. Mitchell relates to an analogous subject, to which, as M. Magendie[4] has observed, little or no attention had been paid by physiologists,—the *permeability of membranes by gases*. "The laminæ," M. Magendie remarks, "of which membranes are constituted, are so arranged that gases can penetrate

[1] Amer. Journal of the Medical Sciences for November, 1833, p. 100.

[2] Magendie, Leçons sur les Phénomènes Physiques de la Vie, tom. i. p. 99, Paris, 1836–38.

[3] Henle, Allgem. Anat., or Jourdan's French translat., p. 210, Paris, 1843; and Wagner, Elements of Physiology, by Willis, p. 438, Lond., 1842.

[4] Précis Elémentaire de Physiologie, 2de édit., 1825, i. 13; and Lecons, &c., tom. i. p. 132.

them, as it were, without obstacle. If we take a bladder, and fill it with pure hydrogen, and afterwards leave it in contact with atmospheric air, in a very short time the hydrogen will have lost its purity, and be mixed with the atmospheric air, which has penetrated the bladder. This phenomenon is more rapid in proportion as the membrane is thinner and less dense. It presides over one of the most important acts of life—respiration; and continues after death."

Dr. Mitchell is the first individual, who directed his observation to the relative penetrativeness of different gases. This he was enabled to discriminate by the following satisfactory experiment, which we give in his own words: "Having constructed a syphon of glass, with one limb three inches long, and the other ten or twelve inches, the open end of the short leg was enlarged and formed into the shape of a funnel, over which, finally, was firmly tied a piece of thin gum elastic. By inverting this syphon, and pouring into its longer limb some clear mercury, a portion of common air was shut up in the short leg, and was in communication with the membrane. Over this end, in the mercurial trough, was placed the vessel containing the gas to be tried, and its velocity of penetration measured by the time occupied in elevating to a given degree the mercurial column in the other limb. Having thus compared the gases with common air, and subsequently by the same instrument, and in bottles with each other, I was able to arrange the following gases according to their relative facility of transmission, beginning with the most powerful:—ammonia, sulphuretted hydrogen, cyanogen, carbonic acid, nitrous oxide, arseniuretted hydrogen, olefiant gas, hydrogen, oxygen, carbonic oxide, and nitrogen."

He found that *ammonia* transmitted in one minute as much in volume as *sulphuretted hydrogen* did in two minutes and a half; *cyanogen*, in three minutes and a quarter; *carbonic acid*, in five minutes and a half; *nitrous oxide*, in six minutes and a half; *arseniuretted hydrogen*, in twenty-seven minutes and a half; *olefiant gas*, in twenty-eight minutes; *hydrogen*, in thirty-seven minutes and a half; *oxygen*, in one hour and fifty-three minutes; and *carbonic oxide*, in two hours and forty minutes. It was found, too, that up to a pressure of sixty-three inches of mercury, equal to more than the weight of two atmospheres, the penetrative action was capable of conveying the gases—the subjects of the experiment—into the short leg through the gum elastic membrane. Hence, the degree of force exerted in the penetration is considerable.

The experiments were all repeated with animal membranes, such as dried bladder and gold-beater's skin, moistened so as to resemble the natural state. The same results, and in the same order, followed as with the gum elastic. The more fresh the membrane, the more speedy and extensive was the effect; and in living animals the transmission was very rapid.

To these experiments there will be frequent occasion to refer in the course of this work.[1]

[1] See, connected with this subject, the ingenious papers by Dr. Robert E. Rogers, and Dr. Draper,—the former in the American Journal of the Medical Sciences, May, 1836, p. 13;

All these different properties of animal solids are independent of the vital properties. They continue for some time after the total extinction of life in all its phenomena, and appear to be connected either with the physical arrangement of the molecules, the chemical composition of the substance in which they reside, or with peculiar properties in the body that is made to act on the tissue. They do not, indeed, seem to be affected, until the progress of decomposition has become sensible. Hence, many of them have been termed collectively, by Haller, *vis mortua*.

2. FUNCTIONS OF MAN.

Having described the intimate structure of the tissues, we pass to the consideration of the functions; the character of each of which is, —that it fulfils a special and distinct office in the economy, for which it has in general an organ or instrument, or evident apparatus of organs. Physiologists have not, however, agreed on the number of distinct offices; and hence the difference, in regard to the number and classification of the functions, that prevails amongst them. The oldest division is into the *vital*, *natural*, and *animal;* the *vital functions* including those of such importance as not to admit of interruption,—circulation, respiration, and innervation; the *natural functions* those that effect nutrition, digestion, absorption, and secretion; and the *animal*, those possessed exclusively by animals,—sensation, locomotion, and voice. This classification, with more or less modification, prevails at the present day.

The character of this work will not admit of a detail of every classification which has been proposed; that of Bichat, however, has occupied so large a space in the public eye, that it cannot well be passed over. It is followed by M. Richerand,[1] and many modern writers. Bichat includes all the functions under two heads,—*functions of nutrition*, which concern the *life of the individual*, and *functions of reproduction*, which concern the *life of the species*. Nutrition requires, that the being shall establish relations around him to obtain the materials of which he may stand in need; and, in animals, the functions that establish such relations, are under the volition and perception of the being. Hence they are divided into two sets; those that commence or precede nutrition; have external relations; are dependent upon the will, and executed with consciousness; and those that are carried on within the body spontaneously, and without consciousness. Bichat adopted this basis; and, to the first aggregate of functions, he applied the term *animal life*, because it comprised those that characterize animality; the latter he termed *organic life*, because the functions comprised under it are common to every organized body. *Animal life* included sensation, motion, and expression; *organic life*, digestion, absorption, respiration, circulation, nutrition, secretion, &c. In animal life, Bichat recognized

and the latter in the same Journal for August, 1836, p. 276; Nov. 1837, p. 122; and Aug. 1838, p. 302.

[1] Nouveaux Elémens de Physiologie, 13ème édit., par M. Bérard, ainé, édit. Belge, p. 42, Bruxelles, 1837; or Amer. reprint of Copland's edit. of De Lys's translation, New York, 1836.

two series of actions, antagonistic to each other; the one proceeding from without and terminating in the brain, or passing from circumference to centre, and comprising the external senses; the other, commencing in the brain, and acting on external bodies, or proceeding from centre to circumference, and including the internal senses, locomotion, and voice. The brain, in which one series of actions terminates and the other begins, he considered the centre of animal life. In organic life, he likewise recognized two series of actions: the one, proceeding from without to within, and effecting composition; the other passing from within to without, and effecting decomposition. In the former, he included digestion; absorption; respiration, by which the blood is formed; circulation, by which the blood is conveyed to different parts; and the functions of nutrition, and calorification. In the latter, that absorption by which parts are taken up from the body; the circulation, which conducts those parts or materials to the secretory or depuratory organs; and the secretions, which separate them from the economy. In this kind of life, the circulation is common to the two movements of composition and decomposition; and, as the heart is the great organ of the circulation, he considered it the centre of organic life. Lastly, as the lungs are united with animal life in the reception of air, and with organic life as the organs of sanguification, Bichat regarded them as the bond of union between the two lives. Generation constituted the *life of the species.*

The classification, adopted in this work, is essentially that embraced by M. Magendie;[1] and, after him, by M. Adelon,[2] who has written one of the best systems of human physiology that we possess. The FIRST CLASS, or *functions of relation or animal functions*, includes those that establish our connexion with the bodies that surround us; the *sensations*, *voluntary motions*, and *expressions*. The SECOND CLASS, or *functions of nutrition*, comprises *digestion*, *absorption*, *respiration*, *circulation*, *nutrition*, *calorification*, and *secretion;* and the THIRD CLASS, the *functions of reproduction,—generation.*

TABLE OF FUNCTIONS.

I. Functions that relate to the preservation of the individual.	I. Animal or of Relation.	1. Sensation.
		2. Muscular Motion.
		3. Expression or Language.
	II. Nutritive.	4. Digestion.
		5. Absorption.
		6. Respiration.
		7. Circulation.
		8. Nutrition.
		9. Calorification.
		10. Secretion.
II. Functions that relate to the preservation of the species.	III. Reproductive.	11. Generation.

In studying each of these functions, we shall first of all describe the organ or apparatus concerned in its production,—but so far only as is necessary in a physiological point of view; and shall next detail what has been called the *mechanism* of the function, or the mode in which it is effected. In many cases, it will happen, that some external agent

[1] Précis, &c., i. 32.

[2] Physiologie de l'Homme, 2de édit., i. 116. Paris, 1829.

is concerned,—as *light* in vision; *sound* in audition; *odours* in olfaction; *tastes* in gustation. The properties of these agents will, in all instances, be detailed in a brief manner.

The difficulty of observing actions, that are carried on by the very molecules of which the organs are composed, has given rise to many hypothetical speculations, some of which are sufficiently ingenious; others too fanciful to be indulged for a moment; and, as might be expected, the number of these fantasies generally bears a direct proportion to the difficulty and obscurity of the subject. It will not be proper to pass over the most prominent of these, but they will not be dwelt upon; whilst the results of direct observation and experiment will be fully detailed; and where differences exist amongst observers, such differences will be reconciled, where practicable.

The functions, executed by different organs of the body, can be deduced by direct observation; although the minute and molecular action, by which they are accomplished in the very tissue of the organ, may not admit of detection. We see blood proceeding to the liver, and the vessels that convey it ramifying in the texture of that viscus, and becoming so minute as to escape detection even when the eye is aided by a powerful microscope. We find, again, other canals in the organ becoming perceptible, gradually augmenting in size, and ultimately terminating in a larger duct, which opens into the small intestine. If we examine each of these orders of vessels in their most minute appreciable ramifications, we discover, in the one, always blood; and, in the other, always a very different fluid,—bile. We are hence led to the conclusion, that in the intimate tissue of the liver, and in some part communicating directly or indirectly with both these orders of vessels, bile is separated from the blood; or that the liver is the organ of the biliary secretion. On the other hand, functions exist, which cannot be so demonstratively referred to a special organ. We have every *reason* for believing, that the brain is the exclusive organ of the mental and moral manifestations; but, as few opportunities occur for seeing it in action; and as the operation is too molecular to admit of direct observation when we do see it, we are compelled to connect the organ and function by a process of reasoning only; yet, we shall find, that the results at which we arrive in this manner are often by no means the least satisfactory.

The forces which preside over the various functions are either *general*,—that is, physical or chemical; or *special*,—that is, organic or vital. Some of the organs afford us examples of purely physical instruments. We have in the eye, an eye-glass of admirable construction; in the organ of voice, an instrument of music; in the ear, one of acoustics: the circulation is carried on through an ingenious hydraulic apparatus; and station and progression involve various laws of mechanics. In many of the functions, again, we have examples of chemical agency, whilst all in which innervation is concerned are incapable of being explained on any physical or chemical principle; and we are constrained to esteem them *vital*.

BOOK I.

ANIMAL FUNCTIONS OR FUNCTIONS OF RELATION.

THE functions of relation consist, *first*, of sensibility, and, *secondly*, of muscular motion, including expression or language. They are all subject to intermission, constituting *sleep;* a condition which has, consequently, by many physiologists, been investigated under this class; but as the functions of reproduction are influenced by the same condition, the consideration of sleep will be deferred until the third class of functions has received attention.

CHAPTER I.

SENSIBILITY.

SENSIBILITY is the function by which an animal experiences feeling, or has the perception of an impression. In its general acceptation, it means the property possessed by living parts of receiving impressions, whether the being exercising the property has consciousness of it or not. To the first of these cases—in which there is consciousness—Bichat gave the epithet *animal;* to the second, *organic;* the latter being common to animals and vegetables, and presiding over the *organic* functions of nutrition, absorption, exhalation, secretion, &c.; the former existing only in animals, and presiding over the sensations, internal as well as external. *Animal sensibility* will be considered here. It would be well, indeed, to restrict the term sensibility to cases involving consciousness.

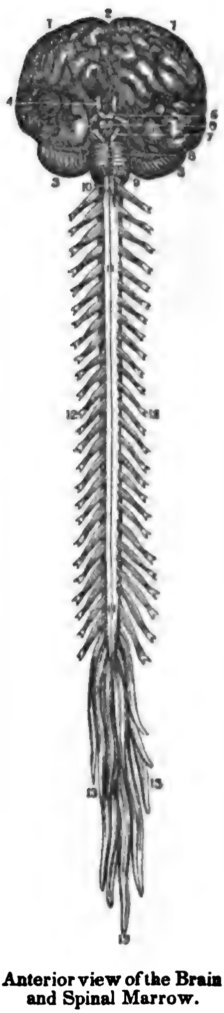
Pursuing the plan already laid down, the study of this interesting and elevated function will be commenced, by pointing out, as far as may be necessary, the apparatus that effects it, the *nervous system.*

1. NERVOUS SYSTEM.

Under the name *nervous system*, anatomists include all those organs that are composed of nervous or pulpy tissue—neurine. In man, it is constituted of three portions: *first*, of what has been called the *cerebro-spinal axis*, a central part having the form of a long cord, expanded at its superior extremity, and contained within the cavities of the cranium and spine; *secondly*, of cords, called *nerves*, in number thirty-nine pairs, according to some,—forty-two, according to others,—passing laterally between the cerebro-spinal axis and every part of the body; and, lastly, of a nervous cord, situate on each side of the spine, from the head to the pelvis, forming *ganglia* opposite each vertebral foramen, and called the *great sympathetic.*

1. *Encephalon.*—Under this term are included the contents of the cranium, namely, the *cerebrum* or *brain proper*, the *cerebellum* or *little brain*, and the *medulla oblongata*. These parts collectively have been by some called *brain*.

Fig. 2.



Anterior view of the Brain and Spinal Marrow.

1, 1. Hemispheres of the cerebrum. 2. Great middle fissure. 3. Cerebrum. 4. Olfactory nerves. 5. Optic nerves. 6. Corpora albicantia. 7. Motor oculi nerves. 8. Pons Varolii. 9. Fourth pair of nerves. 10. Lower portion of medulla oblongata. 11, 11. Medulla spinalis. 12, 12. Spinal nerves. 13. Cauda equina.

When we look at a section of the encephalon, in its natural position, we find many distinct parts, and the appearances of numerous and separate organs. So various, indeed, are the prominences and depressions observable on the dissection of the brain, that it is generally esteemed one of the most difficult subjects of anatomy; yet, owing to the attention paid to it in all ages, it is now one of the structures best understood by the anatomist. This complicated organ presents a striking illustration of the truth, that the most accurate anatomical knowledge does not necessarily teach the function. The elevated actions, which the encephalon has to execute, have, indeed, attracted a large share of the attention of the physiologist,—too often, however, without any satisfactory result; yet it may, we think, be safely asserted, that we have become better instructed regarding the uses of particular parts of the brain, within the last few years, than during the whole of the century preceding.

The encephalon being of extremely delicate organization, and its functions easily deranged, it was necessary that it should be securely lodged and protected from injuries. Accordingly, it is placed in a round, bony case; and by an admirable mechanism is defended against damage from surrounding bodies. Amongst these guardian agents or *tutamina cerebri* must be reckoned:—the hair of the head; the skin; muscles; pericranium; bones of the skull; the diploë separating the two tables of which the bones are composed, and the dura mater.

It is not an easy matter to assign probable uses for the hair on various parts of the body. On the head, its function seems more readily appropriable. It deadens the concussion, which the brain would experience from the infliction of heavy blows, and prevents the skin of the scalp from being injured by the attrition of bodies. In military service, the former of these uses has been taken advantage of; and an arrangement, somewhat similar to that which exists naturally on the head, has been adopted with regard to the helmet. The metallic substance, of which the ancient and modern helmets are formed, is readily thrown into

vibration; and this vibration being communicated to the brain might, after heavy blows, derange its functions more even than a wound inflicted by a sharp instrument. To obviate this, in some measure, the helmet has been covered with horse-hair; an arrangement which existed in the helmet worn by the Roman soldier. There can be no doubt, moreover, that being bad conductors of caloric, and forming a kind of felt which intercepts the air, the hairs may tend to preserve the head of a more uniform temperature. They are likewise covered with an oily matter, which prevents them from imbibing moisture, and causes them to dry speedily. Another use ascribed to them by M. Magendie,[1] is more hypothetical:—that, being bad conductors of electricity, they may put the head in a state of insulation, so that the brain may be less affected by the electric fluid!

It is unnecessary to explain in what manner the different layers of which the scalp is composed; the cellular membrane beneath; the panniculus carnosus or occipito-frontalis muscle; and the pericranium covering the bone, act the parts of tutamina. The most important of these protectors is the bony case itself. In an essay written by a distinguished physiologist,[2] we have some beautiful illustrations of the wisdom of God as displayed in the mechanism of man, and of his skull in particular; and although some of his remarks may be liable to the censures that have been passed upon them by Dr. Arnott,[3] most of them are admirably adapted to the contemplated object. It is impossible, indeed, for the uninitiated to rise from the perusal of his interesting essay, without being ready to exclaim with the poet, "How wonderful, how complicate is man! how passing wonder He that made him such!" Sir Charles Bell attempts to prove, that the best illustration of the form of the head is the dome; whilst Dr. Arnott considers it to be "the arch of a cask or barrel, egg-shell, or cocoa-nut, &c., in which the tenacity of the material is many times greater than necessary to resist the influence of gravity, and comes in aid, therefore, of the curve to resist forces of other kinds approaching in all directions, as in falls, blows, unequal pressures," &c. The remarks of Dr. Arnott on this subject are just; and it is owing to this form of the cranium, that any blow received upon one part of the skull is rapidly distributed to every other; and that a heavy blow, inflicted on the forehead or vertex, may cause a fracture, not in the parts struck but in the occipital or sphenoidal bones.

The skull does not consist of one bone, but of many. These are joined together by *sutures*,—so called from the bones seeming as if they were *stitched* together. Each bone consists likewise of two tables; an external, fibrous, and tough; and an internal, of a harder character and more brittle, hence called *tabula vitrea*. The two are separated from each other by a cellular or cancellated structure, called *diploë*. On examining the mode in which the tables form a junction with each other at the sutures, we find additional evidences of design exhibited.

[1] Précis Elémentaire, edit. cit. i. 177.
[2] Sir Charles Bell, in Animal Mechanics—Library of Useful Knowledge, London, 1829.
[3] Elements of Physics, or Natural Philosophy, General and Medical, London, 1827—reprinted in this country, Philad., 1841.

The edges of the outer table are serrated, and so arranged as to be accurately dovetailed into each other; the tough fibrous texture of the external plate being well adapted for such a junction. On the other hand, the tabula vitrea, which, on account of its greater hardness, would be liable to fracture and chip off, is merely united with its fellow at the suture, by what is called *harmony:* the tables are merely placed in contact.

Fig. 3.

Front view of the Skull.

1. Frontal portion of the frontal bone. 2. Nasal tuberosity. 3. Supra-orbital ridge. 4. Optic foramen. 5. Sphenoidal fissure. 6. Spheno-maxillary fissure. 7. Lachrymal fossa, and commencement of the nasal duct. 8. Opening of the anterior nares, and the vomer. 9. Infra-orbital foramen. 10. Malar bone. 11. Symphysis of the lower jaw. 12. Mental foramen. 13. Ramus of the lower jaw. 14. Parietal bone. 15. Coronal suture. 16. Temporal bone. 17. Squamous suture. 18. Great ala of the sphenoid bone. 19. Commencement of the temporal ridge. 20. Zygoma of the temporal bone. 21. Mastoid process.

The precise object of the sutures is not apparent. In the mode in which ossification takes place in the bones of the skull, the radii from different ossific points must necessarily meet by the "law of conjugation," in the progress of ossification. This has, by many, been esteemed the cause of the sutures; but the explanation is insufficient. Howsoever it may be, the kind of junction affords a beautiful example of adaptation. During the fœtal state, the sutures do not exist. They are fully formed in youth; are distinct in the adult age; but in after periods of life become entirely obliterated, the bone then forming a solid spheroid. It does not seem that after the sutures are established, any displacement of the bones can take place; and observation has shown, that they do not possess much, if any, effect in putting a limit to fractures. In all cases of severe blows, the skull appears to resist as if it were constituted of one piece. But the separation of the skull into distinct bones, which have a membranous union, is of striking advantage to the fœtus in parturition. It enables the bones to overlap each other; and, in this way, to occupy a much smaller space than if ossification had united them as in after life. It has, indeed, been imagined by some, that there is this advantage in the pressure made on the brain by the investing bones,—that the fœtus does not suffer from the violent efforts made to extrude the child; but, during the passage through the pelvis, is in a state of fortunate insensibility; and pressure suddenly exerted upon the brain is certainly attended with these effects,—a fact, which has to be borne in mind in the management of apoplexy, fracture of the skull, &c.

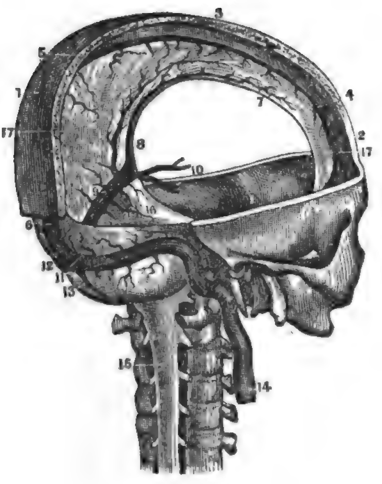
The uses of the *diploë*, which separates the two tables of the skull, are not equivocal. Composed of a cancellated structure, it is well adapted to deaden the force of blows; and as it forms, at the same time, a bond of union and of separation, a fracture might be inflicted upon the outer table of the skull, and yet be prevented from extending to the tabula vitrea. Such cases have occurred, but they are rare. It

will generally happen, that a blow, intended to cause serious bodily injury, will be sufficient to break through both tables, or neither.

Lastly, the *dura mater*, which has been reckoned as one of the tutamina cerebri, lines the skull, and constitutes a kind of internal periosteum to it. It may also be inservient to useful purposes, by deadening the vibrations, into which the head may be thrown by sudden concussions; as the vibrations of a bell are arrested by lining it with a soft material. It is chiefly, however, to protect the brain against itself, that we have the arrangement which prevails. The cerebrum, as well as the cerebellum, consists of two hemispheres; and its posterior part is situate immediately above the cerebellum. It is obvious, then, that without some protection, the hemisphere of one side would press upon its fellow, when the head is inclined to the opposite side; and that the posterior lobes of the brain would weigh upon the cerebellum in the erect attitude.

The *hemispheres* are separated from each other by the *falx cerebri*, in the upper margin of which is the *superior longitudinal sinus*. The falx passes between the hemispheres. The *tentorium cerebello superextensum*—a prolongation of the dura mater—passes horizontally forwards so as to support the posterior lobes of the brain, and prevent them from pressing injuriously on the *cerebellum*. A process of the dura mater passes also between the hemispheres of the cerebellum. Independently of the protection afforded to the encephalon, the dura mater lodges the great sinuses into which the veins discharge their blood. These different sinuses empty themselves into the *torcular Herophili* or *confluence of the sinuses;* and ultimately proceed to constitute the *lateral sinuses*, which pass through the temporal bone, and form the *internal jugular veins*.

Fig. 4.



Falx Cerebri and Sinuses of upper and back part of Skull.

1, 2, 3. Section of the bones of the cranium, showing the attachment of the falx major. 4. Anterior portion of superior longitudinal sinus. 5. Middle portion. 6. Inferior portion; the outer table of the cranium removed. 7. Commencement of the inferior longitudinal sinus. 8. Its termination in the straight sinus. 9. Sinus quartus or rectus. 10. Vena Galeni. 11. One of the lateral sinuses. 12. Torcular Herophili. 13. Sinus of the falx cerebelli. 14. Internal jugular vein. 15. Dura mater of the spinal marrow. 16. Tentorium cerebelli. 17, 17. Falx cerebri.

The tutamina are not confined to the contents of the cranium. The spine appears to be, if possible, still better protected. In the skull, we see a firm, bony case; in the spine, a structure admitting considerable motion of the parts, without risk of pressure to the marrow. Accordingly, the spine consists of numerous distinct bones or vertebræ, with fibro-cartilaginous—technically called *intervertebral*—substances placed between each, so that, although the extent of motion between any two of these bones may be small, when all are concerned, it is considerable. The great use of this interver-

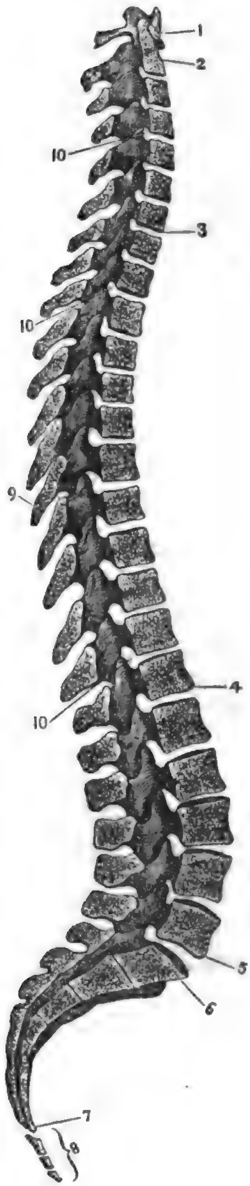
tebral substance is to prevent the jar, that would necessarily be communicated to the delicate parts within the cavities of the spine and cranium, were the spine composed entirely of one bone. In falls from a height upon the feet or breech, these elastic cushions are forcibly compressed; but they immediately return to their former condition, and deaden the force of the shock. In this they are aided by the curvatures of the spine, which give it the shape of the Italic *ſ*, and enable it to resist—in the same manner as a steel spring—any force acting upon it in a longitudinal direction. So well is the medulla spinalis protected by the strong bony processes jutting out in various directions from the spine, that it is extremely rare to meet with lesions of the marrow; and it is comparatively of late years that any *ex professo* treatises have appeared on the subject.

Besides the protection afforded by the bony structure to the delicate medulla, M. Magendie[1] has pointed out another, which he was the first to detect. The canal, formed by the dura mater around the spinal cord, is much larger than is necessary to contain that organ; but, during life, the whole of the intermediate space is filled with a serous fluid, which strongly distends the membrane, so that it will frequently spirt out to a distance of several inches, when a puncture is made in the membrane. To this fluid he has given the epithet *cephalo-spinal;* and he conceives, that it may act as one of the tutamina of the marrow—which is, as it were, suspended in the fluid—and exert upon it the pressure necessary for the healthy performance of its functions.

Beneath the dura mater is a very delicate membrane, the *arachnoid*, belonging to the class of serous membranes. It surrounds the encephalon in every part; but is best seen at the base of the brain.

Its chief use is to secrete a thin fluid, to

Fig. 5.

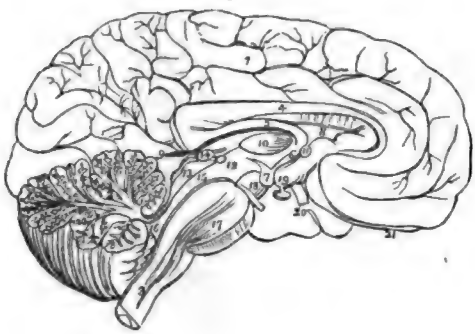


Lateral View of the Spinal Column.

1. Atlas. 2. Dentata. 3. Seventh cervical vertebra. 4. Twelfth dorsal vertebra. 5. Fifth lumbar vertebra. 6. First piece of sacrum. 7. Last piece of sacrum. 8. Coccyx. 9. A spinous process. 10, 10. Intervertebral foramina.

[1] Précis, &c., édit. cit. i. 181. For an elaborate description of the fluid, see Magendie, Recherches Physiologiques, &c., sur le Liquide céphalo-rachidien, Paris, 1842; and Dr. Todd, Cyclop. of Anat. and Physiol., part xxv. p. 639, Lond., 1844.

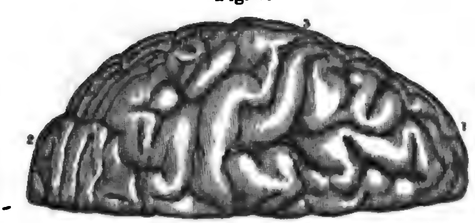
Fig. 6.



Longitudinal Section of the Brain on the Mesial Line.

1. Inner surface of the left hemisphere. 2. Divided surface of the cerebellum, showing the arbor vitæ. 3. Medulla oblongata. 4. Corpus callosum, continuous with 5, the fornix. 6. One of the crura of the fornix descending to 7, one of the corpora albicantia. 8. Septum lucidum. 9. Velum interpositum, communicating with the pia mater of the convolutions through the fissure of Bichat. 10. Section of the middle commissure in the third ventricle. 11. Section of the anterior commissure. 12. Section of the posterior commissure; the commissure is somewhat above and to the left of the number. The interspace between 10 and 11 is the foramen commune anterius, in which the crus of the fornix (6) is situate. The interspace between 10 and 12 is the foramen commune posterius. 13. Corpora quadrigemina, upon which is the pineal gland, 14. 15. Iter a tertio ad quartum ventriculum. 16. Fourth ventricle. 17. Pons Varolii, through which are passing the diverging fibres of the corpora pyramidalia. 18. Crus cerebri of the left side, with the third nerve arising from it. 19. Tuber cinereum, from which projects the infundibulum having the pituitary gland appended to its extremity. 20. One of the optic nerves. 21. Left olfactory nerve.

Fig. 7.



The Convolutions of one Side of the Cerebrum, as seen from above.

1. Anterior lobe of the cerebrum. 2. Posterior lobe. 3. Middle lobe.

lubricate the brain. This membrane enters into all the cavities of the organ, and in them fulfils a like function. When the fluid accumulates to a great extent, the resulting disease is *hydrocephalus chronicus.*

Anatomists usually describe a third tunic of the brain—the *pia mater.* This is generally conceived to consist of the minute terminations of the cerebral arteries, and those of the corresponding veins; forming at the surface of the brain a vascular network, which passes into the cavities; and, in the ventricles, forms the *plexus choroides* and *tela choroidea.* The dura and pia mater were so called by the older anatomists, because they were conceived to be the origin of all the other membranes of the body.

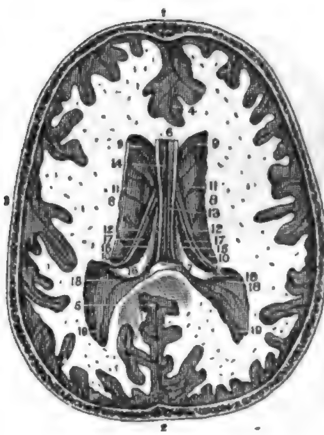
The *cerebrum* or *brain proper* has the form of an oval, larger behind. On its outer surface are various undulating eminences, called *convolutions,* because they have been thought to resemble the folds of the intestines. They are separated from each other by depressions called *anfractuosities.* They form the *hemispherical ganglion* of Mr. Solly. In the brain of man, these convolutions are larger than in animals; and the anfractuosities deeper. In different brains, the number, size, and arrangement of these vary. They are not the same, indeed, in the same individual; those of the right hemisphere being disposed differently from those of the left.

The hemispheres, it has been seen, are separated *above* by the falx cerebri: *below,* they are united by a white medullary commissure, *corpus callosum, mésolobe* or *great commissure,—great transverse commissure* of Mr. Solly. If we examine the brain at its base, we find that each hemisphere is divided into three lobes,—an *anterior,* which rests

on the vault or roof of the orbit,—a *middle* or *temporal*, filling the middle and lateral parts of the base of the cranium, and separated from the former by a considerable depression, called *fissure of Sylvius*,—and a *posterior*, which rests on the tentorium cerebelli. This part of the cerebrum is divided into two very distinct portions by the medulla oblongata. Anterior to it are the *crura cerebri* or *cerebral peduncles*—by most anatomists considered to be a continuation of the anterior fasciculi which form the spinal marrow and medulla oblongata, and proceeding to form the hemispheres of the brain. Between the anterior extremities of the peduncles are two hemispherical projections, called *eminentiæ mammillares*, which are possessed by man exclusively; have the shape of a pea; and are formed of white nervous tissue externally, of gray within. Anterior to these again is the *infundibulum;* and a little farther forwards, the *chiasma* of the optic nerves or the part at which these nerves come in contact.

Laterally, and at the inferior surface of the anterior lobes, is a groove or furrow, running from behind to before, and from without to within, in which the *olfactory nerve* is lodged. At the extremity of this furrow is a tubercle, which is trifling in man, but in certain animals is equal to the rest of the brain in bulk. From this the olfactory nerve has been conceived to arise. It is called the *olfactory tubercle* or *lobe*.

Fig. 8.



Superior Part of the Lateral Ventricles, Corpora Striata, Septum Lucidum, Fornix, &c., as given by a Transverse Section of the Cerebrum.

1. Section of the os frontis. 2. Section of the os occipitis. 3. Section of the ossa parietalia. 4, 5. Anterior and posterior extremities of the middle fissure of the cerebrum. 6. Anterior extremity of the corpus callosum. 7. Its posterior extremity joining the fornix. 8, 8. Point to where the corpus callosum joins the lateral medullary matter of the cerebrum. 9. Its place of junction anteriorly. 10. Posterior point of union. 11. Middle portion of the corpora striata (lateral ventricle). 12. Tænia striata. 13. Septum lucidum. 14. Fifth ventricle. 15. Fornix. 16. Posterior crura. 17. Plexus choroides. 18. Ergot or hippocampus minor. 19. Posterior crura of the lateral ventricle.

When we examine the interior of the brain, we find a number of parts to which the anatomist assigns distinct names. Of these the following chiefly concern the physiologist. It has been already remarked, that the corpus callosum forms at once the bond of union and of separation between the two hemispheres. It is distinctly perceived, in the form of a long and broad white band, on separating these parts from each other. Beneath the corpus callosum is the *septum lucidum* or median septum, which passes perpendicularly downwards, and separates from each other the two largest cavities of the brain—the *lateral ventricles*. It is formed of two laminæ, which leave a cavity between them, called the *fifth ventricle*. The *fornix* or *inferior longitudinal commissure* of Mr. Solly, whose office is to connect the anterior and posterior parts of the same hemisphere, as the transverse commissures do those of the opposite hemisphere, is placed horizontally below the last. The band of

fibres which runs in each hemisphere above the corpus callosum, on the edge of the longitudinal fissure, is the *superior longitudinal commissure* of Mr. Solly. Its use is supposed to resemble that ascribed to the inferior longitudinal commissure. The fornix is of a triangular shape; and constitutes the upper paries of another cavity—the third ventricle. Beneath the fornix, and behind, are the *pineal gland* and its peduncles, forming the *pineal commissure* of Mr. Solly, respecting which so much has been said, by Descartes,[1] and others, as the seat of the soul. Within it is a small cavity; and, after six or seven years of age, it always contains some concretions. Again, anterior to the pineal gland, and immediately below the fornix, is another cavity—the *third ventricle.* Its bottom is very near the base of the brain, and is formed by the nervous layer which unites the peduncles of the brain with the eminentiæ mammillares. At the sides, it has the thalami nervorum opticorum.

Fig. 9.

Section of the Cerebrum, displaying the surfaces of the Corpora Striata, and Optic Thalami, the cavity of the Third Ventricle, and the upper surface of the Cerebellum.

a, *e*. Corpora quadrigemina,—*a* testis, *e* nates. *b*. Soft commissure. *c*. Corpus callosum. *f*. Anterior pillars of fornix. *g*. Anterior cornu of lateral ventricle. *k*, *k*. Corpora striata. *l*, *l*. Optic thalami. * Anterior tubercle of the left thalamus. *x* to *s*. Third ventricle. In front of *x*, anterior commissure. *b*. Soft commissure. *s*. Posterior commissure. *p*. Pineal gland with its peduncles. *n*, *n*. Processus a cerebello ad testes. *m*, *m*. Hemispheres of the cerebellum. *h* Superior vermiform process. *i*. Notch behind the cerebellum.

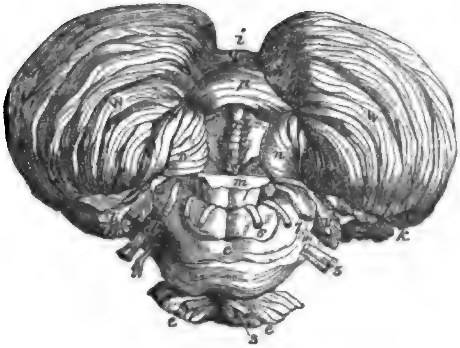
In the lateral ventricles, situate on each side of the corpus callosum, some parts exist which demand attention. In the upper or anterior half, commonly called *anterior cornu*, and in the anterior part of this, two pyriform eminences are seen, of a brownish-gray colour, which, owing to their being formed of an assemblage of alternate layers of white and gray substance, are called *corpora striata*, the *anterior cerebral ganglions* of Mr. Solly. Behind these, are two whitish medullary bodies called *thalami nervorum opticorum—posterior cerebral ganglions*—which are situate before the corpora quadrigemina, and envelope the anterior extremities of the crura cerebri.

Three main sets of fibres may be distinguished in the medullary substance, of which the great mass of the cerebrum is composed. *First*, the ascending fibres, which proceed from the sensory tract of the medulla spinalis, and diverge from the thalami optici to the periphery of

[1] Tractatus de Homine, p. 5.

the brain; *secondly*, the descending fibres, which converge from the periphery towards the corpora striata, and then pass downwards to the motor tract of the medulla spinalis; and, *thirdly*, the commissural fibres, which establish a connexion between the various parts of the periphery, and of the substance of the brain. The bulk of the human brain, and of that of the higher animals, is greatly dependent upon the large proportion borne by these last fibres to the rest.[1]

Fig. 10.

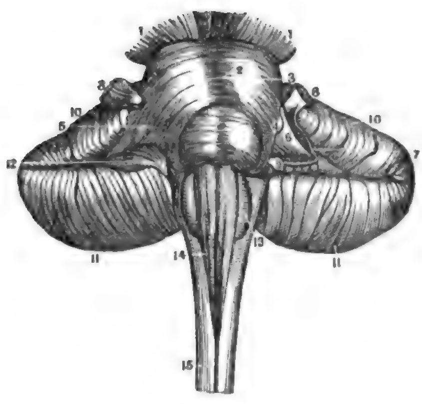


An under View of the Cerebellum, seen from behind.

The medulla oblongata, *m*, having been cut off a short way below the pons. (Reil.) *c*. Pons Varolii. *d*. Middle crus of cerebellum. *e*, *e*. Crura cerebri. *i*. Notch on posterior border. *k*. Commencement of horizontal fissure. *l*. Flocculus, or subpeduncular lobe. *m*. Medulla oblongata cut through. *q*. to *s*. The inferior vermiform process, lying in the vallecula. *p*. Pyramid. *r*. Uvula. *n*, *n*. Amygdalæ. *s*. Nodule, or laminated tubercle. *x*. Posterior velum, partly seen. *w*. Right and left hemispheres of cerebellum. 3 to 7. Nerves. 3, 3. Motores oculorum. 5. Trigeminal. 6. Abducent nerve. 7. Facial and auditory nerves.

The *cerebellum* occupies the lower occipital fossæ, or the whole of the cavity of the cranium beneath the tentorium cerebelli. Its size and weight, like those of the brain, differ according to the individual, and the age of the subject under examination. We do not observe convolutions in it. It appears rather to consist of laminæ in superposition, separated from each other by furrows. We shall see, hereafter, that the number of cerebral convolutions has been esteemed, in some respects, to accord with the intellect of the individual; and Malacarne asserts, that he has observed a similar correspondence, as regards the number of laminæ composing the cerebellum; that he found only three hundred and twenty-four in the cerebellum of an insane individual; whilst in others he had counted upwards of eight hundred.

Fig. 11.



Posterior Superior View of the Pons Varolii, Cerebellum, and Medulla Oblongata and M. Spinalis.

1, 1. Crura cerebri. 2. Pons Varolii or tuber annulare. 3. Its middle fossa. 4. Oblique band of medullary matter seen passing from its side. 5. External surface of the crus cerebelli. 6. Same portion deprived of outer layer. 7. Nervous matter which unites it to 4. 8. Trigeminus or fifth pair of nerves. 9. Portion of the auditory nerve. The white neurine seen passing from the oblique band which comes from the corpus restiforme to the trigeminus nerve in front, and the auditory nerve behind. 10, 11. Superior portion of the hemispheres of the cerebellum. 12. Lobulus amygdaloides. 13. Corpus olivare. 14. Corpus pyramidale. 15. Medulla spinalis.

From the medullary part of the cerebellum, two large white cords pass to the pons Varolii,

[1] Carpenter, Human Physiology, p. 215. Lond., 1842.

having the same disposition as the crura cerebri. They are the *crura cerebelli.*

Owing to the peculiar arrangement of the white and gray cerebral substances, when one of the hemispheres of the cerebellum is divided vertically, an arborescent appearance is presented,—the trunks of the arborization being white, the surrounding substance gray. This appearance is called *arbor vitæ.* The part where all these arborizations meet, near the centre of the cerebellum, is called *corpus denticulatum* vel *rhomboïdale.* Gall was of opinion, that this body has great agency in the production of the cerebellum. Lastly, the cerebellum covers the posterior part of the medulla oblongata, and forms with it a cavity, called *fourth ventricle.*

The *medulla oblongata* is so called, because it is the continuation of

Fig. 12.

Analytical Diagram of the Encephalon—in a Vertical Section. (After Mayo.)

s. Spinal cord. *r.* Restiform bodies passing to *c*, the cerebellum. *d.* Corpus dentatum of the cerebellum. *o.* Olivary body. *f.* Columns continuous with the olivary bodies and central part of the medulla oblongata, and ascending to the tubercula quadrigemina and optic thalami. *p.* Anterior pyramids. *v.* Pons Varolii. *n*, *b.* Tubercula quadrigemina. *g.* Geniculate body of the optic thalamus. *t.* Processus cerebelli ad testes. *a.* Anterior lobe of the brain. *q.* Posterior lobe of the brain.

the medulla spinalis in the cavity of the cranium. It is likewise termed *mésocéphale*, from its being continuous with the spinal marrow in one direction, and sending towards the brain strong prolongations—crura cerebri; and to the cerebellum similar prolongations—crura cerebelli; so that it appears to be the bond of union between these various parts. In its lower portion, it seems to be merely a continuation of the medulla spinalis, except that it is more expanded superiorly where it joins the pons Varolii. This portion of the medulla oblongata is called, by some, *tail of the medulla oblongata;* by others, the *rachidian bulb;* and, by others again, it is regarded as the medulla oblongata. Its lower surface rests on the basilary gutter of the occipital bone, and exhibits a groove which divides the spinal cord into two portions. On each side of this furrow are two oblong eminences, the innermost of which is called *corpus pyramidale,* the outermost, *corpus olivare,* which arise from the anterior column of the medulla spinalis, or are a continuation and subdivision of this column. These oval bodies are surrounded by a superficial groove, which, in some instances, is partially interrupted by some arciform fibres, which cross it at its lower part. At the lower third of the medulla oblongata, fibres of the anterior pyramids decussate, and form an anatomical demarcation between the medulla oblongata and the spinal cord. The decussation takes place by from three to five bundles of fibres from each pyramidal body. This decussation, as will be seen, hereafter, is interesting in regard to the cross effect induced by certain diseases of the brain. On the posterior surface of the medulla oblongata, the posterior fasciculi separate to form the fourth ventricle: at the sides of this ventricle are the *corpora restiformia,* or *inferior peduncles of the cerebellum,* —so called because they seem to aid in the formation of that part of the encephalon; and on the inner side of each corpus restiforme is the small body—the *posterior pyramid.* Again, in addition to the corpora pyramidalia and olivaria—which derive their origin from, or are continuous with, the anterior fasciculi of the spinal cord, and are destined, according to some, to form the brain—and the corpora restiformia, which are continuations of the posterior fasciculi, and are destined to form the cerebellum, there exists, according to some anatomists, other fasciculi in the rachidian bulb. All these are interesting points of anatomy, but are not of so much importance physiologically; notwithstanding even the views promulgated by Sir Charles Bell.[1] He considers that a column exists between the corpora olivaria and corpora restiformia,

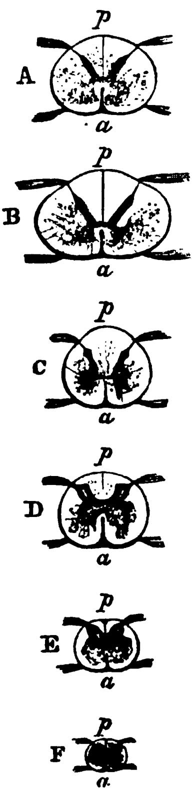
Fig. 13.

Anterior View of the Medulla Oblongata, showing the decussation of the Pyramids, and of the upper part of the Spinal Cord. (After Mayo.)

p. Anterior pyramids. *r.* Restiform bodies. *o.* Olivary bodies. *d.* Decussating fibres. *al.* Antero-lateral column of the spinal cord. *c.* Anterior fissure of the cord, the floor of which forms the anterior commissure.

[1] The Nervous System of the Human Body: from Transactions of the Royal Society from 1821 to 1829, London, 1830. Reprinted in this country, Washington, 1833.

Fig. 14.



Transverse Sections of the Spinal Cord.

A. Immediately below the decussation of the pyramids. B. At middle of cervical bulb. C. Midway between cervical and lumbar bulbs. D. Lumbar bulb. E. An inch lower. F. Very near the lower end. *a*. Anterior surface. *p*. Posterior surface. The points of emergence of the anterior and posterior roots of the nerves are also seen.

which extends below through the whole spine, but above does not proceed farther than the point where the rachidian bulb joins the tuber annulare; and that this column gives origin to a particular order of nerves—the respiratory. The corpora olivaria, and the posterior corpora pyramidalia, are regarded by Mr. Solly[1] as ganglia;—the former of the function of respiration,—the latter of the sense of hearing.

The anterior and upper half of the medulla oblongata bears the names *pons Varolii*, *tuber annulare*, and *nodus cerebri;* and to this are attached, superiorly, the *corpora* or *tubercula quadrigemina.* In the very centre of the pons, the crura cerebri bury themselves; and by many, they are considered to decussate; by others, to be prolongations of the anterior column of the spinal marrow. Sir C. Bell thinks, that the pons Varolii stands in the same relation to the lateral portions of the cerebellum, that the corpus callosum does to the cerebrum;—that it is the great commissure of the cerebellum, uniting its lateral parts, and associating the two organs.

The medulla oblongata consists chiefly of the centres of the nerves of respiration and deglutition, which, as elsewhere shown, are strictly reflex in their action.

2. The *spinal marrow* extends, in the vertebral canal from the foramen magnum of the occipital bone above to the first or second lumbar vertebra, where it terminates in the *cauda equina.* It is chiefly composed of medullary matter, but not entirely so. Within, the cineritious substance is ranged irregularly, but has a crucial form when a section is made. The marginal illustrations exhibit sections of the spinal cord of man at different points; and the proportion of gray and white matter at each. From the calamus scriptorius in the fourth ventricle, and the rima formed by the corpora pyramidalia before, two fissures extend downwards, which divide the spinal marrow into lateral portions. The two lateral portions are divided into an anterior and a posterior, so that the cord has four distinct portions. By some, indeed, it is conceived to consist of three columns—an *anterior*, *posterior*, and a *middle* or *lateral.*

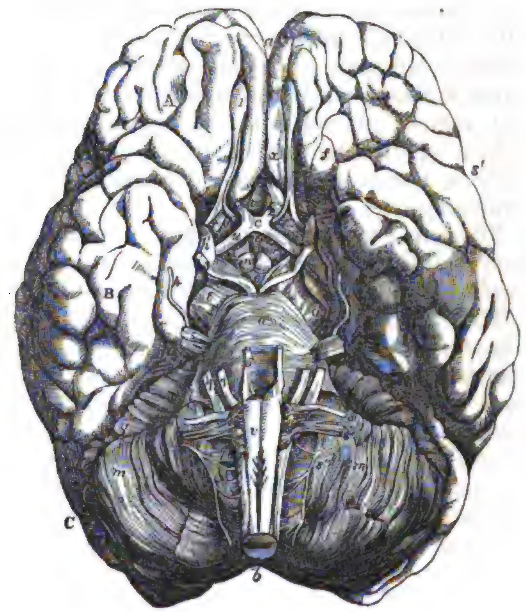
The vertebral canal is lined by a strong ligamentous sheath, running down its whole length. The dura mater likewise envelopes the medulla at the occipital foramen, being firmly united to the ligaments; but farther down it constitutes a separate tube. The tunica arachnoidea from

[1] The Human Brain, its Configuration, Structure, Development, and Physiology, &c., p. 147, London, 1836. See, on this subject, Dr. John Reid, on the Anatomy of the Medulla Oblongata, in Edinb. Med. and Surg. Journ., Jan., 1841, p. 12.

the brain adheres loosely to the cord, having the cephalo-spinal fluid within it; and the pia mater closely embraces it.

3. *Nerves.*—The nerves are cords of the same nervous substance as that which composes the encephalon and spinal marrow; extending from these parts, and distributed to the various organs of the body, many of them interlacing in their course, and forming *plexuses:* others having knots or *ganglions*, and almost all vanishing in the parts to which they are distributed. The generality of English anatomists reckon thirty-nine pairs of nerves; the French, with more propriety, forty-two. Of these, nine, according to the English—twelve, according to the French—draw their origin from, or are connected with, the encephalon; and are hence called *encephalic* nerves; and thirty from the medulla spinalis; and hence termed *spinal.* The encephalic nerves emerge from the cranium by means of foramina at its base. They are — proceeding from before to behind — the *first pair* or *olfactory*, distributed to the organ of smell; the *second pair* or *optic*, the expansion of which forms the retina; the *third pair*, *motores oculi* or *common oculo-muscular*, which send filaments to most of the muscles of the eye; the *fourth pair*, *trochleares*, *pathetici* or *internal oculo-muscular*, distributed to the greater oblique muscle of the eye; the *fifth pair*, *trifacial*, *trigemini*, or *symmetrical nerve of the head*, (Bell,) which send their branches to the eye, nose, and tongue; the *sixth pair*, *abducentes* or *external oculo-muscular*, which are distributed to the abductor or rectus externus oculi; the *facial nerve*, *portio dura* of the seventh pair,

Fig. 15.



Shows the under Surface or Base of the Encephalon freed from its Membranes.

A, anterior, B, middle, and C, posterior lobe of cerebrum.—*a.* The fore part of the great longitudinal fissure. *b.* Notch between hemispheres of the cerebellum. *c.* Optic commissure. *d.* Left peduncle of cerebrum. *e.* Posterior perforated space. *e* to *i.* Interpeduncular space. *f, f'.* Convolution of Sylvian fissure. *h.* Termination of gyrus fornicatus behind the Sylvian fissure. *i.* Infundibulum. *l.* Right middle crus or peduncle of cerebellum. *m, m.* Hemispheres of cerebellum. *n.* Corpora albicantia. *o.* Pons Varolii, continuous at each side with middle crura of cerebellum. *p.* Anterior perforated space. *q'.* Horizontal fissure of cerebellum. *r.* Tuber cinereum. *s, s'.* Sylvian fissure. *t.* Left peduncle or crus of cerebrum. *u, u.* Optic tracts. *v.* Medulla oblongata. *x.* Marginal convolution of the longitudinal fissure.—1 to 9 indicate the several pairs of cerebral nerves, numbered according to the usual notation, viz., 1. Olfactory nerve. 2. Optic. 3. Motor nerve of eye. 4. Pathetic. 5. Trifacial. 6. Abducent nerve of eye. 7. Auditory, and 7'. Facial. 8. Glosso-pharyngeal, 8'. Vagus, and 8''. Spinal accessory nerve.

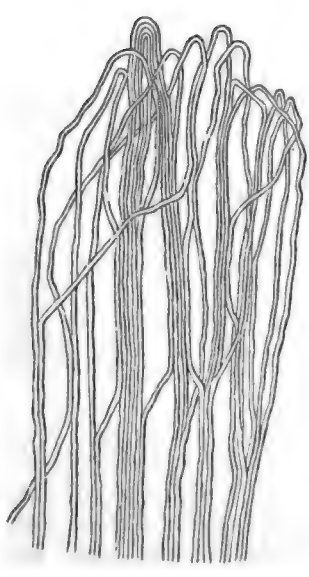
nervus communicans faciei or *respiratory nerve of the face*, distributed to the muscles of the face; the *acoustic nerve*, *auditory nerve* or *portio mollis* of the seventh pair, which passes to the organ of hearing; the *eighth pair*, *pneumogastric*, *par vagum* or *middle sympathetic*, which is dispersed particularly on the larynx, lungs, heart, and stomach; the *glosso-pharyngeal*, often considered as part of the last, and whose name indicates its distribution to the tongue and pharynx; the great *hypo-glossal*, *ninth pair* or *lingual nerve* distributed to the tongue; and the *spinal accessory* of Willis, which arises from the spinal cord in the cervical region; ascends into the cranium, and issues by one of the foramina to be distributed to the muscles of the neck.. All these proceed, perhaps, from the medulla oblongata;—the brain and cerebellum not furnishing one.

The spinal nerves are thirty in number on each side. They make their exit by the intervertebral foramina, and are divided into eight *cervical*, twelve *dorsal*, five *lumbar*, and five or six *sacral*.

The encephalic nerves are irregular in their formation, and, with the exception of the fifth pair, originate from one root. Each of the spinal nerves arises from two fasciculi, the one anterior, and the other posterior: these roots are separated from each other by the *ligamentum denticulare;* but they unite beyond this ligament, and near the intervertebral foramen present one of those knots, known under the name of *ganglions* or *ganglia*, in the formation of which the posterior root is alone concerned.

When the nerves have made their exit from the cranium and spine, they proceed to the organs to which they have to be distributed; ramifying more and more, until they are ultimately lost sight of, even when vision is aided by a powerful microscope. It is not positively decided, whether the nervous fibres have any distinct terminations either in the nervous centres, or in the organs to which they are distributed. In the gray matter of the brain of the vertebrata, they would appear to form a kind of plexus of loops; and the ultimate fibres do not seem to anastomose. The following has been described as the mode in which the nervous fibres are generally distributed to the peripheral organs. The trunks subdivide into small fasciculi, each of which consists of from two to six fibres, and these form plexuses, whose arrangement bears a general resemblance to that of the elements of the tissue in which they are placed. The primitive fibres then separate; and each, after passing over several elementary parts of the contain-

Fig. 16.



Terminal nerves, on the sac of the second molar tooth of the lower jaw, in the sheep; showing the arrangement in loops. (After Valentin.)

ing tissue, or after forming a single narrow loop, as in the sensory papillæ, returns to the same or to an adjoining plexus, and pursues its way to the nervous centre from which it set out. According to this view, there is no more a termination of nerves, than there is of blood-vessels. Both form circles. More recent observations seem, however, to have demonstrated, that in different situations the loop-like appearance is fallacious; and that the ultimate fibres divide into fibrils, the terminations of which are lost in the tissues.

Investigations, again, by Henle and Kölliker[1] show, that some of the peripheral nervous fibrils terminate in small bodies, seated especially in the nerves of the fingers and toes, which, from their having been discovered, in 1830, by Pacini of Padua, have been called *Pacinian corpuscles;* but of whose uses little can be said. They have not been observed on any motor nerves, so that they would not seem to have anything to do with motion. They exist in many nerves of the sympathetic class, and are not present on many sensitive nerves; so that, it has been properly inferred, they are probably not connected with acuteness of sensation.

Fig. 17.
A

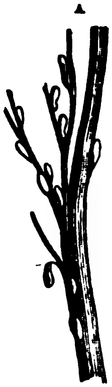
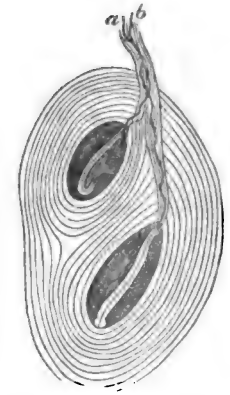


Fig. 18.
B



Pacinian Corpuscles.

A. Nerve from the finger, natural size; showing the Pacinian corpuscles.

B. Unusual form, from the mesentery of the cat; showing two included in a common envelope:—*a*, *b* are the two nerve-tubes belonging to them.

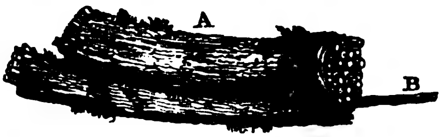
Of the encephalic nerves, the olfactory, auditory, and acoustic —nerves of special sensibility— clearly pass on to their destination, without communicating with any other nerve. The spinal nerves, at their exit from the intervertebral foramina, divide into two branches, an anterior and a posterior, one being sent to each aspect of the body. The anterior branches of the four superior cervical pairs form the *cervical plexus*, from which all the nerves of the neck arise; the last four cervical pairs and the first dorsal form the *brachial plexus*, whence proceed the nerves of the upper extremities; whilst the branches of the five lumbar nerves, and the five sacral form the *lumbar* and *sciatic plexuses;* the former of which gives rise to the nerves distributed to the parts within the pelvis; the second to those of the lower limbs. The anterior branches, moreover, at a little distance from the exit of the nerve from the vertebral canal, communicate with an important and unique portion of the nervous system, the *great sympathetic.*

Each nerve consists of numerous fasciculi surrounded by areolar

[1] Ueber die Pacinischen Körperchen an den Nerven des Menschen und der Saugethiere, Zürich, 1844; reviewed in Brit. and For. Med. Rev., January, 1845, p. 78; and Todd and Bowman, Physiological Anat. and Physiology of Man, i. 395, London, 1845, or Amer. edit.; and W. Bowman, Cyclopædia of Anat. and Physiol., by Dr. Todd, pt. xxvii. p. 876, Lond., Mar., 1846.

membrane; and, according to Reil,[1] of an external envelope, called *neurilemma*, which, in the opinion of most anatomists, is nothing more than an areolar envelope, similar to that which surrounds the vessels and muscular fibres.

Fig. 19.

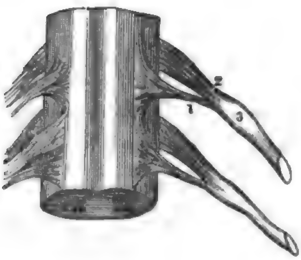


Represents a Nerve consisting of many smaller Cords or Funiculi wrapped up in a common cellular Sheath.

A. The nerve. B. A single funiculus drawn out from the rest. (After Sir C. Bell.)

Until of late years, the nerves were universally divided, according to their origin, into *encephalic* and *spinal;* but, more recently, anatomical divisions have been proposed, based upon the uses they appear to fulfil in the economy. For one of the most beautiful of this kind we are mainly indebted to Sir Charles Bell. It has been already seen, that the encephalic nerves are connected with the encephalon by one root, whilst the spinal nerves arise from two; the one connected with the anterior tract of the spinal marrow, the other with the posterior. If these different roots be experimented on, we meet with results varying considerably. If we divide the anterior root, the part to which the nerve is distributed is deprived of motion; if the posterior root be cut, the part is deprived of sensibility. We conclude, therefore, that each of the spinal nerves consists

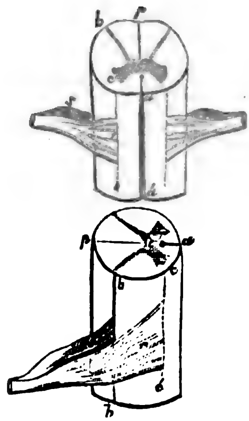
Fig. 20.



A portion of the Spinal Marrow, showing the Origin of some of the Spinal Nerves.

1. Anterior or motor root of a spinal nerve.
2. Posterior or sensory root.
3. Ganglion connected with the latter.

Fig. 21.



Plans in outline, showing the Front A, and the Sides B, of the Spinal Cord, with the Fissures upon it; also sections of the Gray and White Matter, and the Roots of the Spinal Nerves.

a, *a*. Anterior. *p*, *p*. Posterior fissure. *b*. Posterior, and *c*. Anterior horn of gray matter. *e*. Gray commissure. *a*, *e*, *c*. Anterior white column. *c*, *e*, *b*. Lateral columns. *a*, *e*, *b*. Antero-lateral column. *b*, *e*, *p*. Posterior columns. *r*. Anterior, and *s*. Posterior roots of a spinal nerve.

[1] De Structurâ Nervorum, Hal. 1796.

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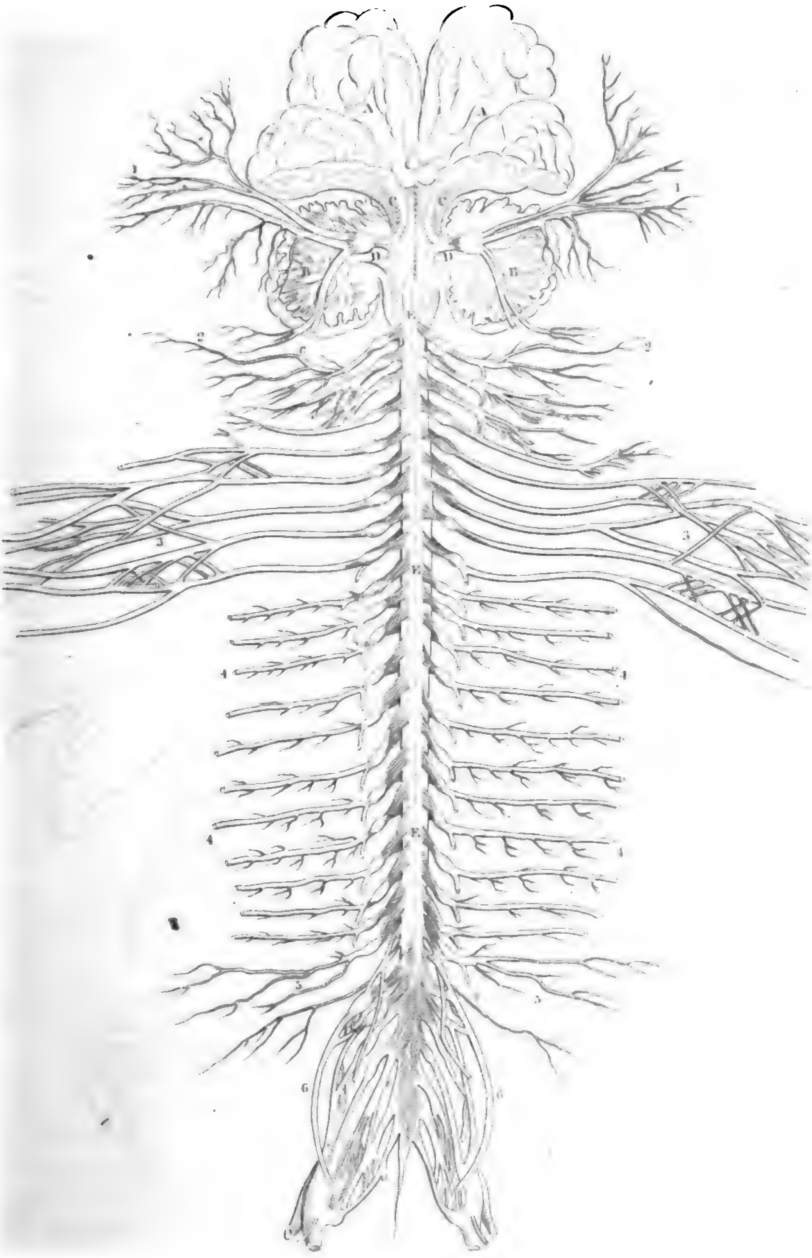
SYSTEM OF RESPIRATORY NERVES.

Sir Charles Bell

REGULAR, OR SYMMETRICAL NERVES.

Sir Charles Bell.



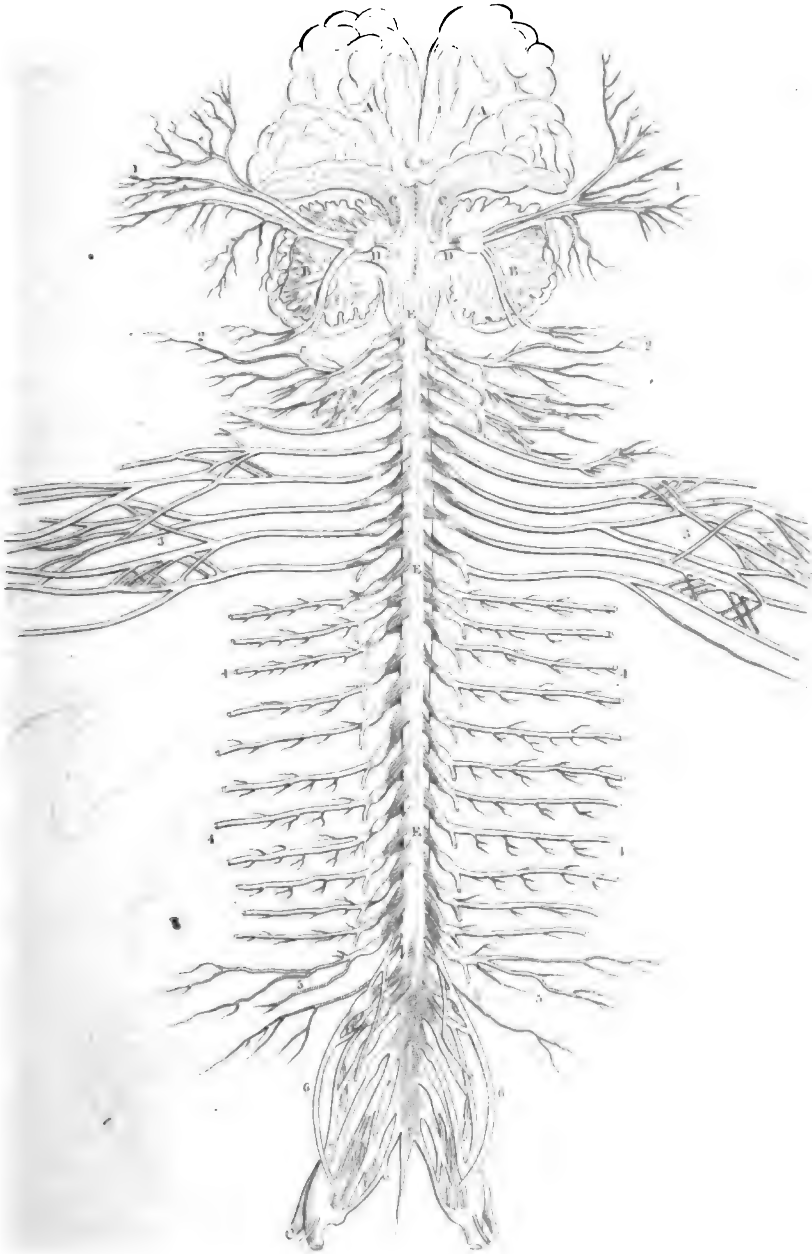
Plate

SYSTEM OF RESPIRATORY NERVES.

Sir Charles Bell.

REGULAR, OR SYMMETRICAL NERVES.

Sir Charles Bell.



of filaments destined for both motion and sensibility; that the encephalic nerves, which have but one root, are destined for one of these exclusively, and that they are either nerves of motion, or of sensation, according as their roots arise from the anterior or the posterior tract of the medulla.

It has already been remarked, that the medulla oblongata, according to some anatomists, is composed of three fasciculi or columns on each side;—an *anterior*, a *middle*, and a *posterior;* and it has been affirmed by Sir Charles Bell, that whilst the anterior column gives origin to nerves of motion; and the posterior to nerves of sensibility; the middle gives rise to a third-order, having the function of presiding over the respiratory movements; and which Sir Charles, accordingly, calls *respiratory nerves.* To this third order belong,—the *accessory nerve* of Willis or *superior respiratory;* the *vagus;* the *glosso-pharyngeal;* the *facial*, called by him the *respiratory nerve of the face;* the *phrenic;* and another having the same origin—the *external respiratory.* Sir Charles's views, if admitted, lead, consequently, to the belief, that there are at least three sets of nerves,—one destined for sensation; another for motion; and a third for a particular kind of motion—the respiratory; and that every nerve of motion communicates to the muscles, to which it is distributed, the power of aiding, or taking part in, motions of one kind or another; so that a muscle may be paralyzed, as regards certain movements, by the section of one nerve, and yet be capable of others of a different kind, by means of the nerves that are uninjured. The accompanying plate exhibits the system of respiratory nerves, as given by Mr. Shaw,[1] son-in-law of Sir Charles Bell, who was prematurely snatched from existence, after having made numerous useful contributions to medical and surgical science.

A, the cerebrum, B, the cerebellum, C C C, the spinal marrow, D, the tongue, E, the larynx, F, the lungs, G, the heart, H, the stomach, I, the diaphragm.

1 1 1. *Par vagum*, arising by a single set of roots and passing to the larynx, lungs, heart, and stomach.

2. *Superior laryngeal branches* of the par vagum.

3. *Recurrent* or *inferior laryngeal branches* of the par vagum.

4. *Pulmonic plexus* of the par vagum.

5. *Cardiac plexus* of the par vagum.

6. *Gastric plexus* of the par vagum.

7. *Respiratory nerve* or *portio dura* passing to the muscles of the face, arising by a series of single roots.

8. Branches of the *glosso-pharyngeal.*

9. *Lingualis*, sending branches to the tongue, and to the muscles on the fore part of the larynx.

10. Origins of the *superior external respiratory* or *spinal accessory.*

11. Branches of the last nerve proceeding to the muscles of the shoulder.

12 12 12. *Internal respiratory* or *phrenic* passing to the diaphragm.

The origins of this nerve are seen to be much higher than they are generally described.

13. *Inferior external respiratory*, to the muscles on the side of the chest.

Yet this division is by no means universally admitted; and even by some who are of opinion, that the sensitive and motor filaments arise from distinct tracts of the spinal cord, it is denied that this is the case with those that originate from the upper part of the cord; there being in the medulla oblongata a blending of the sensitive and motor tracts which cannot easily be explained. Pathological cases, too, occasionally

[1] Manual of Anatomy, &c., 3d edit., Lond., 1822. Reprinted in this country.

occur, which throw great difficulty on this matter. Two of the kind have been related by Mr. Stanley and Dr. Budd,[1] in which there was disease confined to the posterior column; yet sensation remained unimpaired, whilst the power of motion in the lower extremities was lost.

Much evidently remains to be accomplished, before the precise arrangement of the columns of the spinal cord, and of the relations of the nerves connected with them, can be esteemed established. Sir Charles Bell,[2] indeed, subsequently renounced his first opinion, that the posterior roots of the spinal nerves proceed from the posterior column, and described them as arising from the middle or lateral column; affirming, at the same time, that it is not impossible that the posterior column may be connected with the sensitive roots of the spinal nerves, although he has not hitherto succeeded in tracing it. Messrs. Grainger and Swan maintain, that both sets are connected with the lateral columns only; the anterior and posterior lateral fissures definitely limiting the two roots. Perhaps, as suggested by Dr. Carpenter,[3] both these statements may be too exclusive. The anterior roots would seem to have a connexion with both the anterior and lateral columns; and the posterior cannot be said to be restricted to the lateral column, some of their fibres entering the posterior division of the cord.

Most physiologists are now of opinion, both from experiment and reflection, that there is no special column destined for respiration, and that there appears to be nothing so peculiar in the action of the respiratory muscles, that they should require a distinct set of nerves.[4]

Sir C. Bell proposed a further arrangement of the nerves, more natural and philosophical than the unmeaning numeration according to the system of Willis, and better adapted to facilitate the comprehension of this intricate portion of anatomy. According to this, all the nerves of the body may be referred to two great classes—the *original*, *primitive* or *symmetrical*,—and the *irregular* or *superadded*. It has been already remarked, that a division of the spinal cord has been presumed to correspond to the cerebrum; and another to the cerebellum. Now, every *regular nerve* has two roots, one from the anterior of these columns, and another from the posterior. Such are the fifth pair; the sub-occipital; the seven cervical; the twelve dorsal; the five lumbar; and the six sacral,—that is, thirty-two perfect, regular, or double nerves,—including, to state more briefly, all the spinal nerves, and one encephalic—the fifth pair. The fifth pair is found to arise from the encephalon by two roots, and to have a ganglion upon the posterior root. It is, accordingly, classed with the spinal nerves; and, like them, according to Sir Charles Bell, conveys both motion and sensibility to the parts to which it is distributed. These regular nerves are common to all animals, from the zoophyte to man. They run out laterally; or in a direction perpendicular to the longitudinal division of the body; and never take a course parallel to it.

The other class is called *irregular* or *superadded*. The different

[1] Medico-Chirurgical Transactions, vol. xxiii., Lond., 1840.
[2] Nervous System, &c., 3d edit., p. 234. London, 1836.
[3] Principles of Human Physiology, 2d Amer. edit., p. 125. Philad., 1845.
[4] Dr. Reid, op. cit., Jan., 1838, p. 175.

nervous cords, proceeding from it, are distinguished by a simple fasciculus or single root. All these are simple in their origins; irregular in their distribution; and deficient in that symmetry which characterizes those of the first class. They are superadded to the original class; and correspond to the number and complication of the superadded organs. Of these, there are the *third*, *fourth*, and *sixth*, distributed to the eye; the *seventh*, to the face; the *ninth*, to the tongue; the *glosso-pharyngeal*, to the pharynx; the *vagus*, to the larynx, heart, lungs, and stomach; the *phrenic*, to the diaphragm; the *spinal accessory*, to the muscles of the shoulders; and the *external respiratory*, to the outside of the chest. The reason of the seeming confusion in this latter class is to be looked for in the complication of the superadded apparatus of respiration, and in the variety of offices it has to perform in the higher classes of animals.

The accompanying plate exhibits, in one view, the nerves destined to move the muscles in all the varieties of respiration, speech, and facial expression.

In the plate of *regular* or *symmetrical nerves*,

A is the cerebrum, B, the cerebellum, C C, the crura cerebri, D D, the crura cerebelli, E E E, the spinal marrow.

1 1. Branches of the fifth pair, arising from the union of the crura cerebri and crura cerebelli, and having a ganglion at the root. 2 2. Branches of the sub-occipital nerves, which have double origins and a ganglion. 3 3. Branches of the four inferior cervical nerves, and of the first dorsal, forming the axillary plexus. The origins of these nerves are similar to those of the fifth and of the sub-occipital. 4 4 4 4. Branches of the dorsal nerves, which also arise in the same manner. 5 5. The lumbar nerves. 6 6. The sacral nerves.

So much for the anatomy of two great portions of the nervous system. There remains to be considered a third, and by no means the least interesting or important.

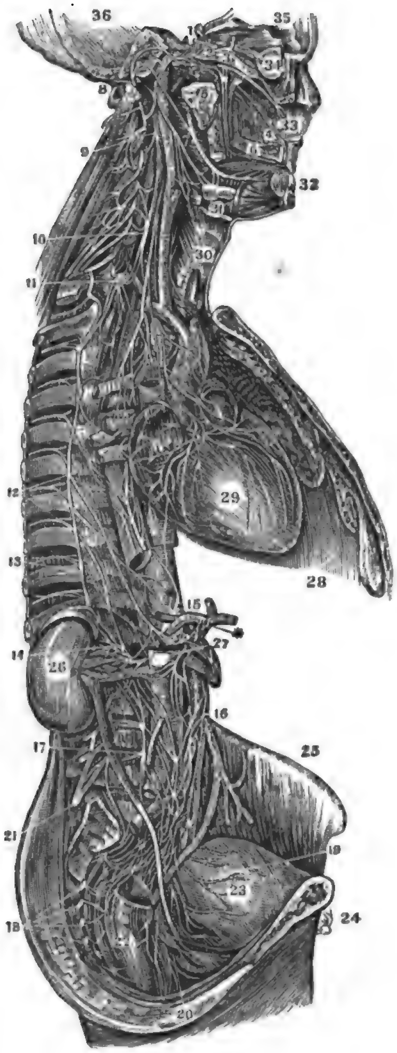
4. *Great Sympathetic.*—This nerve, called also *trisplanchnic*, *splanchnic*, *ganglionic*, *great intercostal*, *vegetative*, and *organic*, is constituted of a series of ganglions, joined to each other by a nervous trunk, and extending down the side of the spine, from the base of the cranium to the os coccygis or lowest bone. It communicates with each of the spinal nerves, and with several

Fig. 22.

Roots of a Dorsal Spinal Nerve, and its union with Sympathetic.

c, *c*. Anterior fissure of the spinal cord. *a*. Anterior root. *p*. Posterior root, with its ganglion. *a'*. Anterior branch. *p'*. Posterior branch. *s*. Sympathetic. *e*. Its double junction with the anterior branch of the spinal nerve by a white and a gray filament.

Fig. 23.



Great Sympathetic Nerve.

1. Plexus on the carotid artery in the carotid foramen. 2. Sixth nerve (motor externus). 3. First branch of the fifth, or ophthalmic nerve. 4. A branch on the septum narium going to the incisive foramen. 5. Recurrent branch or Vidian nerve dividing into the carotid and petrosal branches. 6. Posterior palatine branches. 7. Lingual nerve joined by the chorda tympani. 8. Portio dura of the seventh pair. 9. Superior cervical ganglion. 10. Middle cervical ganglion. 11. Inferior cervical ganglion. 12. Roots of the great splanchnic nerve arising from the dorsal ganglia. 13. Lesser splanchnic nerve. 14. Renal plexus. 15. Solar plexus. 16. Mesenteric plexus. 17. Lumbar ganglia. 18. Sacral ganglia. 19. Vesical plexus. 20. Rectal plexus. 21. Lumbar plexus (cerebro-spinal). 22. Rectum. 23. Bladder. 24. Pubis. 25. Crest of the ilium. 26. Kidney. 27. Aorta. 28. Diaphragm. 29. Heart. 30. Larynx. 31. Submaxillary gland. 32. Incisor teeth. 33. Nasal septum. 34. Globe of the eye. 35, 36. Cavity of the cranium.

of the encephalic; and from the ganglions, formed by such communication, sends off nerves, which accompany the arteries, and are distributed particularly to the organs of involuntary functions. At its upper part, it is situate in the carotid canal, where it appears under the form of a ganglionic plexus; two filaments of which proceed to join the sixth pair of encephalic nerves, and another to meet the Vidian twig of the fifth pair. By means of the fifth pair, it communicates also with the ophthalmic ganglion, which Bichat considered to belong to it. On issuing from the carotid canal, the nerve passes downwards, along the side of the spine, to the sacrum; presenting a series of ganglions;—three in the neck,—the *superior*, *middle*, and *inferior cervical;* twelve in the back,—the *thoracic;* five in the loins,—the *lumbar;* and three or four in the sacrum,—the *sacral.* When it reaches the coccyx, it terminates by a small ganglion, called *coccygeal;* or by uniting with the great sympathetic of the opposite side.

The ganglions are of an irregular, but generally roundish, shape. They consist of nervous filaments, surrounded by a reddish-gray, pulpy, albuminous, or gelatinous substance, which differs from the gray matter of the brain. Sir E. Home[1] considers their structure to be intermediate between that

[1] Lect. on Comp. Anat., v. 194, Lond., 1828.

of brain and nerves; the brain being composed of small globules suspended in a transparent elastic jelly; the nerves made up of single rows of globules, and the ganglions, consisting of a congeries of nervous fibres compacted together.[1] Volkmann and Bidder, and Reichert,[2] consider the sympathetic nerve-fibres to be distinct in size and structure from the cerebro-spinal; but Valentin maintains there is no difference. Authors are by no means agreed with regard to the uses of these ganglions. Willis,[3] Haller,[4] and others, considered them to be small brains for the secretion of the nervous fluid or animal spirits; an opinion, which has been embraced by Richerand,[5] and Cuvier;[6] the latter of whom remarks, that the ganglia are larger and more numerous when the brain is deficient in size. Lancisi,[7] and Vicq d'Azyr, regarded them as a kind of heart for the propulsion of these spirits, or as reservoirs for keeping them in deposit. Scarpa[8] treats them as synonymous with plexuses; but plexuses with the filaments in close approximation; and plexuses he regards as ganglions, the filaments of which are more separated. He consequently believes, with many physiologists, that their office is to commingle and unite various nervous filaments with each other. Dr. Wilson Philip[9] thinks, that they are secondary sources of nervous influence; that they receive supplies of it from all parts of the brain and spinal marrow, and transmit the united influence to the organs to which the nerves are distributed; whilst some conceive, that at least one office is to communicate irritability to the tissues.[10] Johnstone,[11] Reil,[12] Bichat,[13] and others, are of opinion that their use is to render the organs, which derive their nerves from them, independent of the will.

These views are sufficiently discordant; and well indicate the intrinsic obscurity of the subject. That of Dr. Philip is the most probable. Containing the vesicular or gray matter, which seems to be everywhere concerned in the production of nerve-power, the ganglia may be regarded as agents of nervous reinforcement; although we may remain uncertain as to the mode in which their office is executed.[14] It is affirmed

[1] See, on the Histology of the Organic or Sympathetic Nervous Fibres, Mr. Paget, Brit. and For. Med. Rev., July, 1842, p. 279.

[2] Müller's Archiv., 1844, cited by Mr. Paget, in Brit. and For. Med. Rev., April, 1845, p. 572.

[3] Cerebri Anatome, cui accessit Nervorum Descriptio, &c., Lond., 1664, cap. xxvi.

[4] De Verâ Nervi Intercostalis Origine, Gotting., 1793; Collect. Dissert. Anat., ii. 939; and Oper. Minor, i. 503.

[5] See Appendix to Eng. edit., by Dr. Copland.

[6] Leçons d'Anatomie Compar. Introd., p. 26.

[7] Dissert. de Structurâ Usuque Gangliorum, ad J. B. Morgagnium, in Morgagni Adver. Anat., v. 101, Lugd. Bat., 1741.

[8] De Nervis Comment., cap. ii. 320.

[9] Philosoph. Transact. for 1829; and Inquiry into the Nature of Sleep and Death, Lond., 1834, p. 14.

[10] Fletcher, Rudiments of Physiology, P. ii. *a.* p. 68, Edinb., 1836.

[11] Philosophical Transactions, vols. 54, 57, and 60; Essays on the Use of the Ganglions of the Nerves, Shrewsbury, 1771; and Medical Essays and Observations relating to the Nervous System, Evesham, 1795.

[12] Archiv. für die Physiol., s. 226, vii., Halle, 1807.

[13] Anatomie Générale, tom. i. 200, and ii. 405.

[14] See the excellent article by Wagner, entitled Sympathischer Nerv, Ganglienstructur und Nervenendigungen, in his Handwörterbuch der Physiologie, 17te Lieferung, s. 360, Braunschweig, 1847; another by Budge on the Sympathetic, with special relation to the Heart's action, *Ibid.*, s. 406; and on the Sympathetic Ganglia of the Heart by Wagner, *Ibid.*, s. 450.

by M. Robin, in a communication made by him to the *Académie des Sciences*, of Paris, in June, 1847, that the ganglia of the great sympathetic and of the cerebro-spinal nerves enclose the same kind of ganglionary globules, and of elementary tubes, but in different proportions; and hence he does not regard them as separate nervous systems.

Although connected with the brain by the branches of the fifth and sixth pairs of encephalic nerves, and with the spinal cord by the spinal nerves, the sympathetic does not appear to be directly influenced by either; as the functions of the parts to which its ramifications are distributed continue for some time after both brain and spinal marrow have been separated; nay, as in the case of the heart and intestines, after they have been removed from the body. Yet many discussions have been indulged regarding the origin of this important part of the nervous system; some assigning it to the brain, others to the spinal marrow, whilst others again esteem it a distinct nerve, communicating with the brain and spinal cord, but not originating from either; receiving, according to M. Broussais,[1] by the cerebral nerves, the excitant influence, and applying it to movements that are independent of the centre of perception. In like manner, he affirms, when irritation predominates in the viscera, it is conveyed by the ganglionic to the cerebral nerves, which transmit it to the brain. Reil and Bichat, esteeming the sympathetic to be the great nervous centre of involuntary functions, have termed it the *organic nervous system*, in contradistinction to the *animal nervous system*, which presides over the animal functions; whilst Lobstein,[2] who has published an *ex professo* work on the subject, assigns three functions to it. 1. To preside over nutrition, secretion, the action of the heart, and the circulation of the blood; 2. To maintain a communication between different organs of the body; and 3. To be the connecting medium between the brain and abdominal viscera. Remak,[3] who believes that the animal economy possesses two sensoriums,—the one in the cerebro-spinal axis, the other in the ganglionic system,—considers, that as in the cerebro-spinal system of nerves two orders of phenomena occur,—the perception of sensation, and the reaction or reflection of volition; so, in the organic nervous system, two analogous actions take place,—organic perception, or, as it has been called, Hallerian irritability, and reaction or organic reflection, as shown by J. Müller.[4]

From the result of his own researches, Dr. Carpenter[5] inferred, that the sympathetic system does not exist in the lowest classes of animals in a distinct form;—that the nervous system of the invertebrata, taken as a whole, bears no analogy to it, and that as the divisions of this become more specialized, some appearance of a separate sympathetic

[1] A Treatise on Physiology applied to Pathology, translated by Drs. John Bell, and R. La Roche, p. 257, Philad., 1832.

[2] De Nervi Sympath. Human., &c., translated by Dr. Pancoast, Philadelphia, 1831.

[3] Ammon's Monatschrift, June, 1840; and Edinb. Med. and Surg. Journal, Jan., 1841, p. 249.

[4] Elements of Physiology, by Baly, i. 736, Lond., 1838.

[5] Dissertation on the Physiological Inferences to be deduced from the Structure of the Nervous System in the Invertebrated Classes of Animals, Edinb., 1839; reprinted in Dunglison's Med. Library, Philad., 1839; also, his Principles of Human Physiology, p. 111, London, 1842.

presents itself, but it is never so distinct as in the vertebrata; hence he deduces, and with probability, that as the sympathetic system is not developed in proportion to the predominant activity of the functions of organic life, but in proportion to the developement of the higher division of the nervous system, its office is not to preside over the former, but to bring them in relation with the latter; so that the actions of the organs of vegetative life are not dependent upon it, but influenced by it in accordance with the operations of the system of animal life.

Again, the great sympathetic has been esteemed to be the visceral nerve *par excellence*, or the one that supplies the different viscera with their nervous influence,—a part of its office as the nervous system of involuntary functions. On examining the course of the great sympathetic, we find many filaments proceeding from the cervical and thoracic ganglions, interlacing and forming the cardiac plexus, from which the nerves of the heart and great vessels arise. The same thoracic ganglions furnish a branch to each intercostal artery. A nerve of the great sympathetic—called the *great splanchnic* or *visceral*—proceeding from some of the thoracic ganglions, passes through the pillars of the diaphragm into the abdomen, and terminates in the large plexus or ganglion, called the *semilunar;* and this by uniting with its fellow of the opposite side, constitutes the still more extensive interlacing,—the *solar plexus*. From this, numerous filaments proceed, which—by accompanying the coronaria ventriculi, hepatic, splenic, spermatic, renal, superior and inferior mesenteric, and hypogastric arteries—are distributed to the parts supplied with blood by these arteries,—the stomach, liver, spleen, testes, kidneys, intestines, &c. Weber,[1] however, who examined the great sympathetic in different animals, affirms, that the splanchnic may not be the sole *visceral* nerve, but that the eighth pair may share in the function. He states, that the great sympathetic is less developed, the lower the animal is in the scale; whilst the eighth pair is more and more developed as we descend, and at length is the only visceral nerve in some of the mollusca. Sir A. Cooper's[2] experiments satisfied him, that this nerve is essential to the digestive process; but of this we shall have to speak hereafter. In the prosecution of those experiments, he found, that when the great sympathetic was tied on a dog, but little effect was produced: the animal's heart appeared to beat more quickly and feebly than usual; but of this circumstance he could not be positive, on account of the natural quickness of its action. The animal was kept seven days, at which time one nerve was ulcerated through, and the other nearly so, at the situation of the ligatures. Another animal on which the sympathetic had been tied nearly a month before, was still living when he wrote. When the pneumogastric or eighth pair, the phrenic, and the great sympathetic were all tied on each side, "the animal lived little more than a quarter of an hour, and died of dyspnœa."[3]

These experiments would appear to show, either that the great sympathetic is not so indispensable to the economy as has been imagined;

[1] Anatom. Comparat. Nerv. Sympath., Lips., 1817.
[2] Guy's Hospital Reports, vol. i. p. 457, London, 1836.
[3] Ibid., p. 471.

or that it is, in every part, a generator of nervous influence, so that if its connexion with the brain or any other viscus be destroyed, the divided portions may still possess the power of generating nervous agency. But if we admit this as regards the system of the great sympathetic, we shall find, that it is difficult to extend it to detached portions of the nervous system of animal life.

It must be confessed, that our knowledge of the uses of this great division of the nervous system is far from being precise; for whilst some physiologists believe it to be concerned in every involuntary and organic action; Dr. Proctor[1] thinks, that the nearest approach to a positive determination of its use that we can arrive at with our present limited knowledge is, that "it is for the purpose of regulating the tonic contraction of the arterial system, and for nothing else." One distinguished observer, M. Magendie,[2] inquires whether we have sufficient reason for the belief, that it is a nerve at all! and a writer[3] of distinction, Dr. J. C. B. Williams, admits, that nothing is definitely known as to the properties communicated by ganglionic nerves; and he adds, "Before the influence of the ganglionic system can be employed as an element in pathology, its existence must be proved, and its properties defined in physiology: this has not been done."

According to the experiments of M. Flourens,[4] the semilunar is the only ganglion that exhibits any great sensibility; and hence it has been considered as a sort of intervention to connect the viscera with the encephalon.

M. Lepelletier[5] thinks we are justified in dividing the nerves into five classes:—the *first*, comprising the *nerves of special sensibility*,—the olfactory, optic, lingual branch of the fifth pair, and auditory:—the *second*, the *nerves of general sensibility*, the fifth pair; and the spinal nerves, through their posterior root:—the *third*, comprising the *voluntary motors;* the spinal nerves, by their anterior roots, the motores oculorum or common oculo-muscular, the external oculo-muscular, and the hypoglossal:—the *fourth*, *instinctive motors*, involuntary, respiratory nerves of Sir Charles Bell, the pathetic, facial, glosso-pharyngeal, pneumogastric, and spinal accessory; and the *fifth*, *nerves of vital association and nutrition*—the filaments and plexuses of the ganglionic system. Dr. Fletcher[6] adopts a different arrangement. He divides them into *ganglionic* and *cerebro-spinal;* the latter being subdivided into the respiratory, motiferous, sensiferous, and regular; the last including those which communicate both the faculty of sensibility and the stimulus of volition.

[1] Medico-Chirurg. Rev., Jan., 1845, p. 182.
[2] Précis de Physiologie, 2de édit., i. 171. Paris, 1825.
[3] Principles of Medicine, 3d Amer. edit., by Dr. Clymer, p. 200, note, Philad., 1848.
[4] Recherches Expérimentales sur les Propriétés et les Fonctions du Système Nerveux, &c., 2d édit., p. 229, Paris, 1842.
[5] Traité de Physiologie Médicale et Philosophique, iii. 250, Paris, 1832.
[6] Rudiments of Physiology, P. ii. *a*. p. 71, Edinb., 1836.

GANGLIONIC.	CEREBRO-SPINAL.			
Those immediately connected respectively with	Respiratory.	Motiferous.	Sensiferous.	Regular.
The Ophthalmic, The Cavernous, The Otic, The Sphenopalatine, The Sub-maxillary, The three Cervical, The Cardiac, The twelve Dorsal, The Cœliac, The five Lumbar, The five Sacral, and The Coccygeal Ganglions.	The Pathetic, The Facial, The Glosso-pharyngeal, The Pneumo-gastric, The Accessory, The Phrenic, and The External Respiratory.	The Motor Oculi, A part of the lower Maxillary branch of the Trigeminus, The Abductor, The Hypoglossal.	The Olfactory, The Optic, The Ophthalmic branch of the Trigeminus, The Upper Maxillary branch of the Trigeminus, A part of the lower Maxillary branch of the Trigeminus, The Auditory.	The Sub-occipital, The seven Cervical, The twelve Dorsal, The five Lumbar, The five Sacral.

5. *True Spinal, Excito-Motory* or *Reflex Nervous System.*—Dr. Marshall Hall[1] has proposed another division of the nervous system, which is calculated to explain many of the anomalous circumstances we so frequently witness. He proposes to divide all the nerves into

1. The cerebral or sentient and voluntary.
2. The true spinal or excito-motory.
3. The ganglionic or nutrient and secretory.

If the sentient and voluntary functions be destroyed by a blow on the head, the sphincter muscles still contract when irritated, because the irritation is conveyed to the spine, and the reflex action takes place to the muscle so as to throw it into contraction. But if the spinal marrow be now destroyed, the sphincters remain entirely motionless; because the centre of the system is destroyed. Dr. Hall thinks, that a peculiar set of nerves constitute, with the true spinal marrow as their axis, the second subdivision of the nervous system; and as those of the first subdivision are distinguished into sentient and voluntary, these may be distinguished into *excitor* and *motory*. The *first*, or excitor nerves, pursue their course principally from internal surfaces, characterized by peculiar excitabilities, to the vesicular centre of the medulla oblongata and medulla spinalis; the *second* or motor nerves pursue a reflex course from the medulla to the muscles, having peculiar actions concerned principally in ingestion and egestion. The motions connected with the first or cerebral subdivision are sometimes—indeed frequently—*spontaneous;* those connected with the true spinal are, he believes, always excited. Dr. Hall thinks that there is good reason for viewing the fifth, and posterior spinal nerves as constituting an external ganglionic system for the nutrition of the external organs; and he proposes to divide the *ganglionic* subdivision of the nervous system into 1, the *internal* ganglionic, which includes that usually denominated the sympathetic, and probably filaments of the pneumogastric; and 2, the *external* ganglionic, embracing the fifth and posterior spinal nerves. To the *cerebral* system he assigns all diseases of sensation, perception, judgment, and volition,—therefore all painful, mental, and comatose, and some paralytic diseases. To the true *spinal* or *excito-*

[1] Lectures on the Nervous System, London, 1836, and American edit., Philad., 1836. Also, his Lectures on the Theory and Practice of Medicine, in the London Lancet for Feb. 3, and Feb. 7, 1838.

motory system belong all spasmodic and certain paralytic diseases. He adds, that these two parts of the nervous system influence each other both in health and disease, as they both influence the ganglionic system.[1]

The views of Dr. Hall on the excito-motory function have been embraced by Müller,[2] Grainger,[3] Carpenter,[4] and indeed, with more or less modification, by almost all physiologists.[5] Dr. Carpenter inferred from his inquiries, that the actions most universally performed by a nervous system are those connected with the introduction of food into the digestive cavity, and that we have reason to regard this class of actions as every where independent of volition, and perhaps also of sensation, —the propulsion of food along the œsophagus, in man, being of this character;—that for the performance of any action of this nature, a nervous circle is requisite, consisting of an *afferent* nerve, on the peripheral extremities of which an impression is made,—a ganglionic centre, where the white fibres of which that nerve consists terminate in gray matter, and those of the efferent nerve originate in like manner; and an *efferent* trunk conducting to the contractile structure the motor impulse, which originates in some change between the gray and white matter;—that in the lowest animals such actions constitute nearly the entire function of the nervous system,—the amount of those involving sensation and volition being very small; but as we ascend the scale, the evidence of the participation of true sensation in the actions necessary for acquiring food, as shown by the developement of special sensory organs, is much greater; but that the movements immediately concerned with the introduction of food into the stomach remain under the control of a separate system of nerves and ganglia, to the action of which the influence of the cephalic ganglia—the special if not the only seat of sensibility and volition—is not essential; that, in like manner, the active movements of respiration are controlled by a separate system of nerves and ganglia, and are not dependent upon that of sensation and volition, although capable of being influenced by it;— that whilst the actions of these systems are, in the lower tribes, almost entirely of a simply reflex character, we find them, as we ascend, gradually becoming subordinate to the will; and that this is effected by the mixture of fibres proceeding directly from the cephalic ganglia with those arising from their own centres;—that the locomotive organs, in like manner, have their own centres of reflex action, which are independent of the influence of volition, perhaps also of sensation;—that the influence of the will is conveyed to them by separate nervous fibres, proceeding from the cephalic ganglia, and that similar fibres probably convey to the cephalic ganglia the impressions destined to produce sen-

[1] Principles of the Theory and Practice of Medicine, by Marshall Hall, M. D., F. R. S., p. 243, London, 1837, and American edit. by Drs. Bigelow and Holmes, Bost., 1839.

[2] Handbuch der Physiologie, s. 333, and s. 688, Coblenz, 1835, 1837, or the English translation by Dr. Baly, i. 707, London, 1838.

[3] On the Structure and Functions of the Spinal Cord, London, 1837.

[4] Op. cit.

[5] Todd and Bowman, the Physiological Anatomy and Physiology of Man, p. 312. London, 1845.

sations;—that the stomato-gastric, respiratory, and locomotive centres are all united in the spinal cord of the vertebrata, where they form one continuous ganglionic mass, and that the nerves connected with all these likewise receive fibres derived immediately from the cephalic ganglia;—and lastly, that whenever peculiar consentaneousness of action is required between different organs, their ganglionic centres are united more or less closely; and that the trunks themselves are generally connected by bands of communication.

On the whole, in the present state of our knowledge, we are justified, perhaps, in adopting the systematic summary of the functions of the nervous system, and the general purposes to which it is inservient, as given by the writer last cited.[1] 1. The nervous system receives impressions, which, being conveyed by its *afferent* fibres to the sensorium, are there communicated to the conscious mind; and are inservient, in some manner, to the acts of that mind. As the result of these acts, a motor impulse is transmitted along *efferent* nerves to particular muscles, which excites them to contraction. Of these acts the encephalon, and nerves communicating with it, are the organs. 2. Certain parts of the nervous system receive impressions, which are propagated along *afferent* fibres that terminate in ganglionic centres distinct from the sensorium. In these, a reflex motor impulse is thus excited, which is transmitted along *efferent* trunks proceeding from those centres, and excites muscular contraction without any necessary intervention of sensation or volition. The organs of this function are the gray matter of the spinal cord, which is not continuous with the fibrous structure of the brain, and the trunks connected with it. It is the true *spinal* or *excito-motory* system of Dr. Hall. 3. There is yet a division of the nervous system, which appears to have for its object to combine and harmonize the muscular movements immediately connected with the maintenance of organic life. It may likewise influence, and connect with each other the functions of nutrition, secretion, &c.; although these—like the muscular movements immediately connected with the maintenance of organic life—are doubtless essentially independent of it; and—as has been shown—can be carried on where it does not exist. The organ of these acts is the great sympathetic. Of late—as will be seen hereafter—Dr. Carpenter[2] has contended with much force for the existence of a series of sensory ganglia, separate and distinct from those that compose the cerebrum and cerebellum—"ganglia of the nerves of sensation, common and special, which are superposed, as it were, on the medulla oblongata," and which, together, constitute the real sensorium.

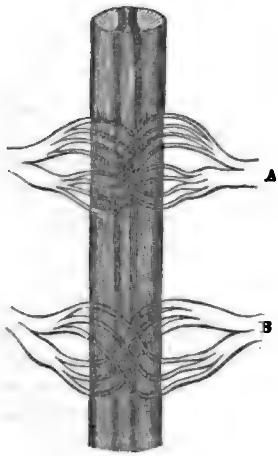
It has been urged by Dr. Laycock,[3] in a paper read before the British Association at York, in accordance with views published by him four years previously, that the brain, although the organ of consciousness, is subject also to the laws of reflex action; and that in this respect it does not differ from other ganglia of the nervous system. He

[1] Human Physiology, p. 79, London, 1842.
[2] Principles of Human Physiology, 4th Amer. edit., p. 320, Philad., 1850.
[3] British and Foreign Medical Review, Jan., 1845, p. 298.

regards the cerebral nerves, and especially the optic, auditory, and olfactory, as afferent excitor nerves, along which impressions pass to the central axis; thence to be communicated to the motor nerves, and thus give rise to combined muscular acts, or to irregular spasmodic movements. Hydrophobia is adduced by him as a good illustration of these cerebral reflex movements. The acknowledged excito-motory phenomena in the disease may be induced.—*First.* Through the nerves of touch, as by the contact of water with the surface of the head, hands, chest, lips, and pharynx. *Secondly.* By a current of air impinging on the face or chest. *Thirdly.* By a bright surface, as a mirror. *Fourthly.* By the sight of water; and *Fifthly.* By the idea of water, as when it is suggested to the patient to drink.

The author has been in the habit of offering as an example of the same kind, vomiting induced by the sight of a disgusting object. Here the impression is first made upon the brain through an organ of sense, and the reflex motor phenomena concerned in vomiting are instantaneously excited;—facts, which at least prove, that although the gray matter of the spinal marrow may continue to execute its functions, when those of the cerebro-spinal nervous system are suspended, —as during sleep or an attack of epilepsy, it is capable of being excited to action by impressions made through the latter, in the same manner as by impressions made on the afferent spinal nerves themselves.

Fig. 24.



Structure of the Spinal Cord, according to Stilling.

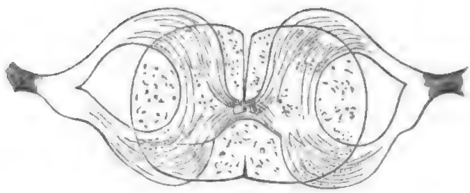
A. Posterior fibres continuous with the anterior of the same side, through the nucleus of the cord. B. Posterior fibres continuous with the anterior of the opposite side.

From all that has been said, it will be understood, that each nerve as it issues from the spinal canal must be composed of various fasciculi:—one, *sensory* or of sensation, connected with the posterior medullary tract, and continuous with the medullary matter of the brain; another, connected with the anterior medullary tract, and conveying the influence of volition from the brain along the spinal cord and nerves to the muscles; a third, consisting of *excitor* fibres, terminating in the gray or ganglionic matter of the cord, and conveying impressions to it; and a fourth, consisting of *motor* fibres, arising from the gray matter of the cord, and conveying the nervous influence reflected to the muscles.

It would appear that a part of each root enters the gray matter of the cord; whilst a part is continuous with the white or medullary matter; and Dr. Stilling[1] affirms—as the result of his researches—that of the fibres of the posterior roots some form loops in the gray matter, and become continuous with those of the anterior roots of the same side; whilst others cross the

[1] Untersuchungen über die Textur des Rückenmarks, von Dr. B. Stilling und Dr. J. Wallach, s. 51. Leipz., 1842.

Fig. 25.



Transverse Section of the Medulla. (After Stilling.)

The transverse gray fibres are the continuation of the roots of the nerves; the longitudinal white and gray fibres are indicated by points.

gray matter, and become continuous with those of the anterior roots of the opposite side. It has been shown, too, by Mr. Newport,[1] that there are other fibres, which pass from the posterior into the anterior roots of other nerves, above and below, both on the same and the opposite side.

Much, doubtless, still remains to be accomplished, before we can consider views in regard to the nervous system established. Like many important questions of physiology, they may be regarded as in a transition state; but the zeal and activity of physiological inquirers are daily throwing light upon many points; and of these there are none surrounded with more obscurity than those that appertain to the nervous system.

All the parts described as constituting the nervous system—brain, cerebellum, medulla spinalis, and nerves—are formed of the primary nervous fibre, the nature of which has been already described. The *neurine* or substance of which they are constituted is soft and pulpy; but the consistence varies in different portions, and, in the whole, at different ages. In the fœtus it is almost fluid; in youth of greater firmness; and in the adult still more so. This softness of structure in the encephalon of the fœtus is by no means inutile. It admits of the pressure, which takes place, to a greater or less extent in all cases of parturition, whilst the head is passing through the pelvis, without the child sustaining any injury. On examining, however, the consistence of different brains, it is necessary to inquire into the period that has elapsed since the death of the individual, as the brain loses its firmness by being kept; and ultimately becomes semifluid. It is likewise rendered fluid by disease, constituting *ramollissement du cerveau* or *mollescence of the brain*, to which the attention of pathologists has been directed of late years, but without much important advantage to science.

When the encephalon is fresh, it has a faint, spermatic, and somewhat tenacious smell. This, according to M. Chaussier, has persisted for years in brains that have been dried.

Neurine has been subjected to analysis by M. Vauquelin,[2] and found to contain, water, 80·00; white fatty matter, 4·53; red fatty matter, called *cerebrin*, 0·70; osmazome, 1·12; albumen, 7·00; phosphorus, 1·50; sulphur, acid phosphates of potassa, lime, and magnesia, 5·15. M. Couerbe's analysis of that of the brain[3] gives, 1. A pulverulent yellow fat, *stearconote;* 2. An elastic yellow fat, *cerancephalote;* 3. A reddish-yellow oil, *eleancephol;* 4. A white fatty matter, *cerebrote,*

[1] Philosophical Transactions, 1843, and Dr. Carpenter, 2d Amer. edit., p. 125, Philad., 1845.
[2] Annales de Chim., lxxxi. 37; and Annals of Philosophy, i. 332.
[3] Annales de Chimie et de Physique, lvi. 160.

the *white fatty matter* of Vauquelin, the *myelocone* of Kühn; 5. Cerebral cholesterin—*cholesterote;* and the salts found by Vauquelin,—lactic acid, sulphur, and phosphorus, which form a part of the fats above-mentioned.[1] In the spinal cord, there is more fatty matter, and less osmazome, albumen, and water. In the nerves, albumen predominates, and fatty matters are less in quantity. Researches by M. Lassaigne show, that water constitutes $\frac{7}{10}$ths of the nerves; and $\frac{8}{10}$ths of the brain; whilst the proportion of albumen in the former is $\frac{22}{100}$ths; in the latter, $\frac{7}{100}$ths. He found the neurine of different parts of the brain to be composed as follows:

	The whole Brain.	White portion.	Gray portion.
Water,	77·0	73·0	85·0
Albumen,	9·6	9·9	7·5
White fatty matter,	7·2	13·9	1·0
Red fatty matter,	3·1	0·9	3·7
Osmazome, lactic acid, and salts,	2·0	1·0	1·4
Earthy phosphate,	1·1	1·3	1·2
	100·0	100·0	100·0[2]

M. Raspail[3] has pointed out two other differences. *First*, when a nerve is left upon a plate of glass in dry air, it becomes dry, without putrefying, whilst cerebral neurine putrefies in twenty-four hours; and *secondly*, the dried nerve has all the physical characters of the corneous substances,—nails, hair, and other analogous bodies; and in their chemical relations, these bodies do not differ sufficiently to repel the analogy. Neither the chemical analysis of neurine, nor inquiry into its minute structure by the aid of the microscope, has, however, thrown light upon the wonderful functions executed by this elevated part of the organism.

It would seem, that neurine is, in composition, intermediate between fat and the compounds of protein: it contains nitrogen, which is not present in fats, but in smaller proportion than in protein; and, on the other hand, it is much richer in carbon than protein or its compounds. Phosphorus, too, is an essential ingredient. According to recent researches by M. Frémy, there is in cerebral neurine a peculiar acid, analogous to the fatty acids, which he calls *cerebric acid*, and which contains nitrogen and phosphorus: this is mixed with an albuminous substance; with an oily acid—*oleo-phosphoric;* with cholesterin; and with small quantities of olein and margarin, and oleic and margaric acids.[4]

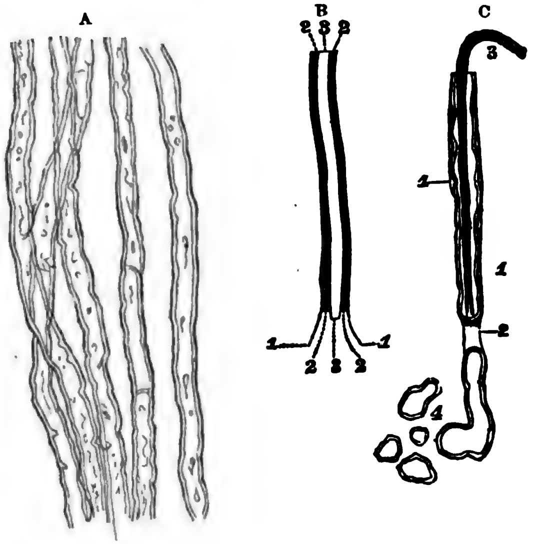
To the naked eye, neurine appears under two forms;—the one gray and of a softer consistence; the other white, and more compact. The former is called the *vesicular*, *gray*, *cortical*, *cineritious*, or *pulpy* substance; the latter, the *tubular*, *white*, *medullary*, or *fibrous*, called "tubular" in consequence of its consisting of tubes of great minuteness, which are filled with a kind of granular pith that can be squeezed from them,—a view adopted by most histologists. Dr. James Stark has,[5]

[1] For John's Analysis of the white and gray cerebral matter, see Journal de Chimie Médicale, Août, 1835. See, also, Simon's Medical Chemistry, p. 81, Lond., 1845.
[2] Journal de Chim. Médic.; and Pharmaceutisches Central Blatt, Nov. 19, 1836, s. 765.
[3] Chimie Organique, p. 217, Paris, 1833.
[4] Journ. des Connais. Méd.-Chir., Jan., 1841; also Turner and Liebig's Chemistry, 7th edit., p. 1195, Lond., 1842.
[5] Proceedings of the Royal Society, No. 56, Lond., 1843.

however, affirmed, as the result of his examination, that the matter which fills the tubes is of an oily nature, differing, in no essential respect, from butter or soft fat, and remaining of a fluid consistence during the life of the animal, or whilst it retains its natural temperature; but becoming granular or solid when the animal dies. The diameter of these cylindrical tubuli has been estimated to vary from about the $\frac{1}{120}$th to the $\frac{1}{240}$th of a line. The nerves are wholly composed of it.

The tubular nervous matter, wherever it is found, seems to consist of fibres, which have a definite arrangement. Two kinds of primitive fibre, according to the researches of Messrs. Todd and Bowman,[1] are present in the nervous system, which they distinguish as the *tubular fibre* or *nerve tube*, and the *gelatinous fibre*,—the former infinitely the more numerous, and the latter found chiefly in the sympathetic system. The tubular fibres vary in diameter from $\frac{1}{1800}$th even to $\frac{1}{10000}$th of an inch; but their average width is from $\frac{1}{2000}$th to $\frac{1}{4000}$th of an inch. The gelatinous fibre is devoid of the whiteness that characterizes the tubular fibre; and the gray colour of certain nerves, it has been thought, is dependent chiefly upon the presence of a large proportion of gelatinous fibres. Hence they have been sometimes termed *gray fibres*. These are in general smaller than the tubular fibres,—their diameter ranging between the $\frac{1}{6000}$th and the $\frac{1}{4000}$th of an inch.

Fig. 26.



Tubular Nerve-fibres.

A. Tubular nerve-fibres, showing the sinuous outline and double contours.

B. Diagram to show the parts of a tubular fibre, viz.: 1, 1. *Membranous tube.* 2, 2. *White substance* or *medullary sheath.* 3. *Axis* or *primitive band.*

C. Figure (imaginary) intended to represent the appearances occasionally seen in the tubular fibres. 1, 1. Membrane of the tube seen at parts where the white substance has separated from it. 2. A part where the white substance is interrupted. 3. Axis projecting beyond the broken end of the tube. 4. Part of the contents of the tube escaped.

Fig. 27.

Gelatinous Nerve-fibres.

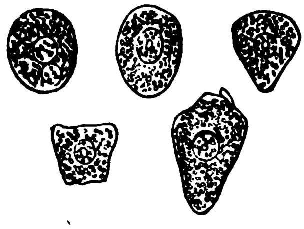
(*a* and *b* magnified 340 diameters, after Hannover; *c* and *d* after Remak.)

[1] Dr. Todd, Art. Nervous Centres, in Cyclop. of Anat. and Phys., Pt. xxvi., p. 707; and The Physiological Anatomy and Physiology of Man, p. 208, London, 1845.

Histologists are generally of opinion, that the central portion of each nerve-fibre differs from the peripheral: the former has been termed by Rosenthal and Purkinje the *axis-cylinder;* the latter is the *medullary* or *white substance of Schwann,* and to it the white colour of the cerebro-spinal nerves is chiefly due.

The researches of histologists have shown that *vesicles* or cells containing nuclei and nucleoli, and called also *nerve corpuscles* and *globules* and *ganglion corpuscles* and *globules,* are the essential elements of gray or vesicular matter. These are found in the nervous centres, mingled with nerve-fibres, and imbedded in a dimly shaded or granular substance. They give to the ganglia and to certain parts of the brain and spinal cord the peculiar grayish or reddish-gray appearance by which they are characterized. They are large nucleated cells, filled with a finely granular material; some of which is often dark, like pigment;—the nucleus, which is vesicular, containing a nucleolus. The marginal figure (Fig. 28) represents some that have a regular outline. Others, as in Fig. 29, are *caudate* or *stellate,* and have tubular processes issuing from them, filled with the same kind of granular matter as is contained in the corpuscle.

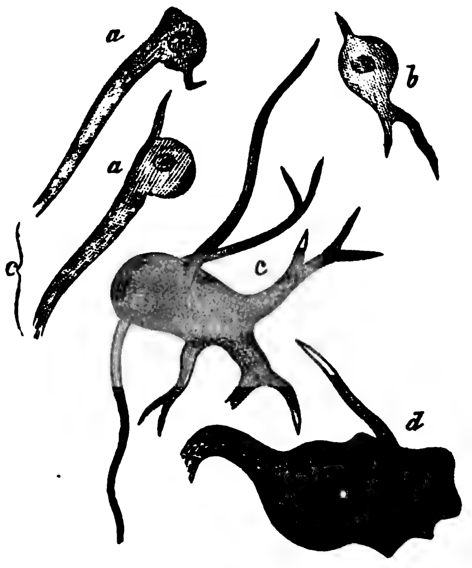
Fig. 28.



Ganglion Corpuscles. After Valentin.

In one a second nucleus is visible. The nucleus of several contains one or two nucleoli.

Fig. 29.



Stellate or Caudate Nerve Corpuscles. After Hannover.

a, a. From the deeper part of the gray matter of the convolutions of the cerebellum. The larger processes are directed towards the surface of the organ. *b.* Another from the cerebellum. *c, d.* Others from the post-horn of gray matter of the dorsal region of the cord. These contain pigment, which surrounds the nucleus in *c.* In all the specimens the processes are more or less broken. Magnified 200 diameters.

The gray substance is not always at the exterior, nor the medullary in the interior. In the medulla spinalis, their situation is the reverse of what it is in the brain. In the invertebrata, the gray matter forms the nuclei of the ganglia, which are the centres of the nervous system; and the true spinal system, which occupies the interior of the spinal cord, has been regarded as a chain of similar ganglia. It is the organ, as already shown, of the excito-motory nervous function. Ruysch considered, that the gray portion owes its colour to the blood-vessels that enter

it;[1] and, in this opinion, Haller, Adelon,[2] and others,[3] concur; but this is not probable, and it has not been by any means demonstrated.[4] The medullary portion has the appearance of being fibrous; and it has been so regarded by Leeuenhoek,[5] Vieussens, Steno, and by Gall and Spurzheim.[6] Malpighi[7] believed the gray cortical substance to be an assemblage of small follicles, intended to secrete the nervous fluid; and the white medullary substance to be composed of the excretory vessels of these follicles; and an analogous view is entertained by most physiologists of the present day,—the gray matter at least being regarded as the generator of the nervous influence; the white matter as chiefly concerned in its conduction. Gall and Spurzheim conjecture, that the use of the gray matter is to be the source or nourisher of the white fibres. The facts, on which they support their view, are, that the nerves appear to be enlarged when they pass through a mass of gray matter, and that masses of this substance are deposited in all parts of the spinal cord where it sends out nerves; but, Tiedemann[8] has remarked, that in the fœtus the medullary is developed before the cortical portion, and he conceives the use of the latter to be—to convey arterial blood, which may be needed by the medullary portion for the due execution of its functions. After all, however, it must be admitted with Dr. Allen Thomson,[9] that the general conclusion deducible from all the facts would seem to be, that whilst the gray fibres predominate in the organic or sympathetic nerves, and the tubular fibres in the cerebro-spinal nerves, these two elements are mixed, in various proportions, in the great divisions of the nervous system; and that, therefore, these divisions, although, in a great measure, structurally different, are not altogether distinct from, or independent of, each other. "But"—he properly adds—"in regard to the whole subject of the structure and nature of the different varieties of the nervous texture, it is unquestionable that much still remains to be ascertained by laborious investigation."

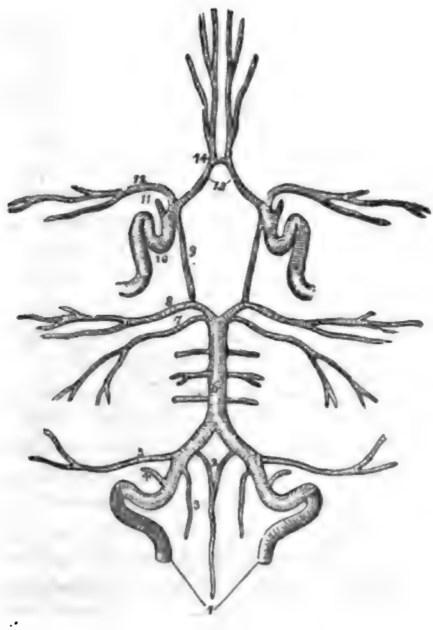
Sir Charles Bell[10] affirms, that he has found, at different times, all the internal parts of the brain diseased, without loss of sense; but he has never seen disease general on the surface of the hemispheres without derangement or oppression of mind during the patient's life; and hence he concludes, that the vesicular matter of the brain is the seat of the intellect, and the tubular of the subservient parts.[11] A similar use has been ascribed to the vesicular portion, from pathological observations, by MM. Foville and Pinel Grandchamp.[12] This view would afford considerable support to the opinions of Gall, Spurzheim, and others, who consider the organs of the cerebral faculties to be constituted of ex-

[1] Oper. Amstel., 1727. [2] Physiologie de l'Homme, 2de édit., i. 208, Paris, 1829.
[3] Carpenter, Human Physiology, p. 81, Lond., 1842.
[4] Todd, Cyclop. of Anat. and Physiol., Pt. xxv. p. 647, Lond., 1844.
[5] Philos. Transact., 1677, p. 899.
[6] Recherches sur le Système Nerveux en général, et sur celui du Cerveau en particulier, avec figures, Paris, 1809.
[7] Oper. Malpighii, and Mangeti Bibl. Anat., i. 321.
[8] Anatomie und Bildungsgeschichte des Gehirns, mit Tafeln, Nürnberg, 1816.
[9] Outlines of Physiology, Pt. i. p. 155, Edinb., 1848.
[10] Anatomy and Physiology, 5th American edit., by J. D. Godman, p. 29, New York, 1827.
[11] See two interesting pathological cases, confirming this view of the function of the gray matter, by Dr. Cowan, in Provincial Medical and Surgical Journal, April 16, 1845.
[12] Sur le Système Nerveux, Paris, 1820.

pansions of the columns of the spinal marrow and medulla oblongata, and to terminate by radiating fibres on the periphery of the brain; as well as to those of M. Desmoulins,[1] and others who regard the convolutions as the seat of the mind. We have, however, cases on record, that signally conflict with this view of the subject; in which the cortical substance has been destroyed, and yet the moral and intellectual manifestations have been little, if at all, injured. Many years ago, the author dissected the brain of an individual of rank in the British army of India, in the anterior lobes of which neither medullary nor cortical portion could be distinguished,—both one and the other appearing to be broken down into a semi-purulent, amorphous substance; yet the intellectual faculties had been nearly unimpaired; although the morbid process must have been of some duration.

The encephalon affords us many striking instances of the different effects produced by sudden, and by gradual interference with its functions. Whilst a depressed portion of bone or an extravasation of blood may suddenly give rise to the abolition of the intellectual and moral faculties, gradual compression by a tumour may scarcely interfere with any of its manifestations.

Fig. 30.



Circle of Willis.

1. Vertebral arteries. 2. Two anterior spinal branches uniting to form a single vessel. 3. One of the posterior spinal arteries. 4. Posterior meningeal. 5. Inferior cerebellar. 6. Basilar artery giving off its transverse branches to either side. 7. Superior cerebellar artery. 8. Posterior cerebral. 9. Posterior communicating branch of the internal carotid. 10. Internal carotid, showing the curvatures it makes within the skull. 11. Ophthalmic artery divided across. 12. Middle cerebral artery. 13. Anterior cerebral arteries connected by, 14. Anterior communicating artery.

The circulation of blood in the encephalon requires notice. The arteries are four in number,—two *internal carotids*, and two *vertebrals:* to these may be added the *spinal* or *middle artery of the dura mater*, *arteria meningæa media*. The carotid arteries enter the head through the carotid canals, which open on each side of the sella turcica, or of the chiasma of the optic nerves. The vertebral arteries enter the head through the foramen magnum of the occipital bone; unite on the medulla oblongata to form the basilary artery, which passes forward along the middle of the pons varolii; and, at the anterior part of the pons, gives off lateral branches, which

[1] Anatomie des Systèmes Nerveux des Animaux à Vertèbres, p. 599, Paris, 1825.

inosculate with corresponding branches of the carotids, and form a kind of circle at the base of the brain, which has been called *circulus arteriosus* of Willis. The passage of the blood-vessels is extremely tortuous, so that the blood does not enter the brain with great impetus; and they become capillary before they penetrate the organ,—an arrangement of importance, when we regard the large amount of blood sent to it. This has been estimated as high as one-eighth of the whole fluid transmitted from the heart. The amount does not admit of accurate appreciation, but it is considerable. It of course varies according to circumstances. In hypertrophy of the heart, the quantity is sometimes increased; as well as in ordinary cases of what are called *determinations* of blood to the head. Here, too large an amount is sent by the arterial vessels; but an equal accumulation may occur, if the return of the blood from the head by the veins be in any manner impeded,—as when we stoop, or compress the veins of the neck by a tight cravat, or by keeping the head turned for a length of time. Congestion or accumulation of blood may therefore arise from very different causes.

Sir Astley Cooper[1] found by experiment, that the vertebral arteries are more important vessels as regards the encephalon and its functions in certain animals, as the rabbit, than the carotids. The nervous power is lessened by tying them; and, in his experiments, the animals did not, in any case, survive the operation more than a fortnight. In the dog, he tied the carotids with little effect, but the ligature of the vertebrals had a great influence. The effect of the operation was to render the breathing immediately difficult and laborious; owing, in Sir Astley's opinion, to the supply of blood to the phrenic nerves, and the whole *tractus respiratorius* of Sir Charles Bell, being cut off. The animal became dull, and indisposed to make use of exertion; or to take food. Compression of the carotids and the vertebrals at the same moment, in the rabbit, destroyed the nervous functions immediately. This was effected by the application of the thumbs to both sides of the neck, the trachea remaining free from pressure. Respiration ceased entirely, with the exception of a few convulsive gasps. The same fact was evinced in a clearer and more satisfactory manner by the application of ligatures to the four vessels, all of which were tightened at the same instant. Stoppage of respiration and death immediately ensued.

The cerebral, like other arteries, are accompanied by branches of the great sympathetic. The researches of Purkinje,[2] Volkmann,[3] and Rainey,[4] have shown the existence of a large number of nerves in connection with the encephalic and spinal arachnoid. They do not seem to communicate with the roots of the spinal nerves, but belong exclusively to the sympathetic.[5] The encephalic veins are disposed as already described, terminating in *sinuses* formed by the dura mater, and conveying

[1] Guy's Hospital Reports, i. 472, London, 1836.

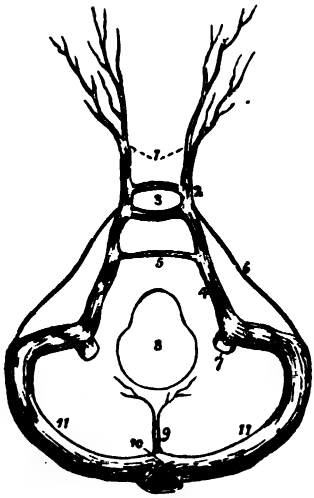
[2] Müller's Archiv. für Anatomie, p. 281, Berlin, 1845.

[3] Art. Nervenphysiologie, Wagner's Handwörterbuch der Physiologie, 10te Lieferung, s. 494, Braunschweig, 1845.

[4] Medico-Chirurgical Transactions for the year 1845.

[5] D. Brinton, Art. Serous and Synovial Membranes, in Cyclop. of Anat. and Physiol., Pt. xxxiv. p. 525, Lond., Jan. 1849.

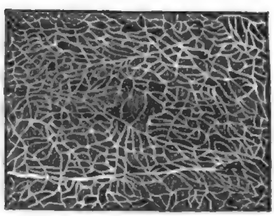
Fig. 31.



Sinuses of the Base of the Skull.

1. Ophthalmic veins. 2. Cavernous sinus of one side. 3. Circular sinus: the figure occupies the position of the pituitary gland in the sella turcica. 4. Inferior petrosal sinus. 5. Transverse or anterior occipital sinus. 6. Superior petrosal sinus. 7. Internal jugular vein. 8. Foramen magnum. 9. Occipital sinuses. 10. Torcular Herophili. 11, 11. Lateral sinuses.

Fig. 32.



Capillary Net-work of Nervous Centres.

their blood to the heart by means of the lateral sinuses and internal jugulars; but of the peculiarities of the circulation in the encephalon, mention will be made in the appropriate place. No lymphatic vessels have been detected in the encephalon; yet, that absorbents exist there is proved by the dissection of apoplectic and paralytic individuals. In these cases, when blood has been effused, the red particles are gradually taken up, with a portion of the fibrinous part of the blood, leaving a cavity called an *apoplectic cell*, which is at the same time the evidence of previous extravasation and subsequent absorption.

The whole of the nervous system is well supplied with bloodvessels. In the vesicular neurine of the nervous centres, the capillaries surround the ganglion cells or globules; and in the tubular they pass between the nerve-tubes, being connected at intervals by transverse branches.

When the skull of the new-born infant, which, at the fontanelles, consists of membrane only—or the head of any one who has received an injury, that exposes the brain—is examined, two distinct movements are perceptible. One, which is generally obscure, is synchronous with the pulsation of the heart and arteries; the other, much more apparent, is connected with respiration, the organ seeming to sink at the time of inspiration, and to rise during expiration. This phenomenon is not confined to the cerebrum, but exists likewise in the cerebellum and spinal marrow. The motion of the encephalon, synchronous with that of the heart, admits of easy explanation. It is owing to the pulsation of the circle of arteries at the base of the brain elevating the organ at each systole of the heart. The other movement is not so readily intelligible. It has been attributed to the resistance, experienced by the blood in its passage through the lungs during expiration, owing to which an accumulation of blood takes place in the right side of the heart; this extends to the veins and to the cerebral sinuses, and an augmentation of bulk is thus occasioned. We shall see hereafter, that one of the forces conceived to propel the blood along the vessels is atmospheric pressure. According to that view, the sinking down of the brain during inspiration is explicable: the blood is rapidly drawn to the heart; the quantity in the veins is consequently diminished; and sinking of the brain succeeds.

On dissection, we find that the encephalon fills the cavity of the cranium; during life, therefore, it must be pressed upon, more or less, by the blood in the vessels, and by the serous fluid exhaled by the pia mater into the subarachnoid tissue. Thence it penetrates into the ventricles, —according to M. Magendie, at the lower end of the fourth ventricle, at the *calamus scriptorius*. The quantity varies according to the age and size of the patient, and usually bears an inverse proportion to the size of the encephalon. It is seldom, however, less than two ounces, and often amounts to five. M. Magendie is of opinion, that the fluid is secreted by the pia mater, and states, that it may be seen transuding from it in the living animal. The results of chemical analysis appear to show, that it differs from mere serum. It is obviously, however, almost impracticable—if not wholly so—to separate the consideration of this fluid from that met with in the cavity of the arachnoid.

The spinal marrow does not, as we have seen, fill the vertebral canal; the cephalo-spinal fluid exerts upon it the necessary pressure; added to which, the pia mater seems to press more upon this organ than upon the rest of the cerebro-spinal system. A certain degree of pressure appears, indeed, necessary for the due performance of its functions; and if this be either suddenly and considerably augmented, or diminished, derangement of function is the result. M. Magendie,[1] however, asserts, that he has known animals, from which the fluid had been removed, survive without any sensible derangement of the nervous functions. It is this fluid, which is drawn off by the surgeon when he punctures in a case of spina bifida.

When the brain is examined in the living body, it exhibits properties, which, some years ago, it would have been esteemed the height of hardihood and ignorance to ascribe to it. The opinion has universally prevailed, that all nerves are exquisitely sensible. Many opportunities will occur for showing, that this sentiment is not founded on fact; even the encephalon itself,—the organ in which perception takes place,—is insensible, in the common acceptation of the term; that is, we may prick, lacerate, cut, and even cauterize it, yet no painful impression will be produced. Experiment leaves no doubt regarding the truth of this, and we find the fact frequently confirmed by pathological cases. Portions of brain may be discharged from a wound in the skull, and yet no pain be evinced. In his "Anatomy and Physiology," Sir C. Bell[2] remarks, that he cannot resist stating, that on the morning on which he was writing, he had had his finger deep in the anterior lobes of the brain; when the patient, being at the time acutely sensible, and capable of expressing himself, complained only of the integument. A pistol-ball had passed through the head, and Sir Charles, having ascertained, that it had penetrated the dura mater by forcing his finger into the wound, trephined on the opposite side of the head, and extracted it.

By the experiments, instituted by MM. Magendie,[3] Flourens and

[1] Précis Elémentaire, seconde édit., i. 192; and Recherches Physiologiques et Cliniques sur le Liquide Céphalo-rachidien ou Cérébro spinal, Paris, 1842.

[2] Fifth Amer. edit. by J. D. Godman, ii. 6, 1827.

[3] Précis Elémentaire, i. 325.

others, it has been shown, that an animal may live days, and even weeks, after the hemispheres have been removed; nay, that in certain animals, as reptiles, no change is produced in their habitudes by such abstraction. They move about as if unhurt. Injuries of the surface of the cerebellum exhibit, that it also is not sensible; but deeper wounds, and especially such as interest the peduncles, have singular results,—to be explained hereafter. The spinal cord is not exactly circumstanced in this manner. Its sensibility is exquisite on the posterior surface; much less on the anterior, and almost null at the centre. Considerable sensibility is also found within, and at the sides of, the fourth ventricle; but this diminishes as we proceed towards the anterior part of the medulla oblongata, and is very feeble in the tubercula quadrigemina of the mammalia.

It has been shown, that the spinal nerves, by means of their posterior roots, convey general sensibility to the parts to which they are distributed. But there are other nerves, which, like the brain, are themselves entirely devoid of general sensibility. This has given occasion to a distinction of nerves into those of *general* and of *special* sensibility. Of nerves, which must be considered insensible or devoid of general sensibility, we may instance the optic, olfactory, and auditory. Each of these has, however, a *special sensibility;* and although it may exhibit no pain when irritated, it is capable of being impressed by appropriate stimuli—by light, in the case of the optic nerve; by odours, in that of the olfactory; and by sound, in that of the auditory. Yet we shall find, that every nerve of special sensibility seems to require the influence of a nerve of general sensibility; the fifth pair.

Many nerves appear devoid of sensibility, as the third, fourth, and sixth pairs; the portio dura of the seventh; the ninth pair of encephalic nerves; and, as has been shown, all the anterior roots of the spinal nerves.

The parts of the encephalon, concerned in muscular motion, will fall under consideration hereafter.

2. PHYSIOLOGY OF SENSIBILITY.

Sensibility we have defined to be—the function by which an animal experiences feeling, or has the perception of an impression. It includes two great sets of phenomena; the *sensations*, properly so called, and the *intellectual* and *moral manifestations*. These we shall investigate in succession.

a. *Sensations.*

A sensation is the perception of an impression made on a living tissue;—or, in the language of Gall, it is the perception of an irritation. By the sensations we receive a knowledge of what is passing within or without the body; and, in this way, our notions or ideas of them are obtained. When these ideas are reflected upon, and compared with each other, we exert *thought* and *judgment;* and they can be recalled with more or less vividness and accuracy by the exercise of *memory*.

The sensations are numerous, but they may all be comprised in two divisions,—the *external* and the *internal*. Vision and audition afford us examples of the former, in which the impression made upon the organ is external to the part impressed. Hunger and thirst are instances of the latter, the cause being internal; necessary; and depending upon influences seated in the economy itself. Let us endeavour to discover in what they resemble each other.

In the first place, every sensation, whatever may be its nature,—external, or internal,—requires the intervention of the encephalon. The distant organ—as the eye or ear—may receive the impression, but it is not until this impression has been communicated to the encephalon, that sensation is effected. The proofs of this are easy and satisfactory. If we cut the nerve proceeding to any sensible part, put a ligature around it, or compress it in any manner;—it matters not that the object, which ordinarily excites a sensible impression, is applied to the part,—no sensation is experienced. Again, if the brain, the organ of perception, be prevented in any way from acting, it matters not that the part impressed, and the nerve communicating with it, are in a condition necessary for the due performance of the function, sensation is not effected. We see this in numerous instances. In pressure on the brain, occasioned by fracture of the skull; or in apoplexy, a disease generally dependent upon pressure, we find all sensation, all mental manifestation, lost; and they are not regained until the compressing cause has been removed. The same thing occurs if the brain be stupefied by opium; and, to a less degree, in sleep, or when the brain is engaged in intellectual meditations. Who has not found, that in a state of reverie or brown study, he has succeeded in threading his way through a crowded street, carefully avoiding every obstacle, yet so little impressed by the objects around as not to retain the slightest recollection of them! On the other hand, how vivid are the sensations when attention is directed to them! Again, we have numerous cases in which the brain itself engenders the sensation, as in dreams, and in insanity. In the former, we see, hear, speak, use every one of our senses apparently; yet there has been no impression from without. Although we may behold in our dreams the figure of a friend long since dead, there can obviously be no impression made on the retina from without.[1]

The whole history of spectral illusions, morbid hallucinations, and maniacal phantasies, is to be accounted for in this manner. Whether, in such cases, the brain reacts upon the nerves of sense, and produces an impression upon them from within, similar to what they experience from without during the production of a sensation, will form a subject for future inquiry. Pathology also affords several instances where the brain engenders the sensation, most of which are precursory signs of cerebral derangement. The appearance of spots flying before the eyes, of spangles, depravations of vision, hearing, &c., and a sense of numbness in the extremities, are referable to this cause; as well as the singular fact well known to the operative surgeon, that pain is often

[1] Adelon, Art. Encéphale (Physiologie), in Dict. de Méd., vii. 514, Paris, 1823, and Physiol. de l'Homme, tom. i. p. 239, 2de édit., Paris, 1829.

felt in part of a limb, months after the limb has been removed from the body.

These facts prove, that every sensation, although referred to some organ, must be perfected in the brain. The impression is made upon the nerve of the part, but the appreciation takes place in the common sensorium.

There are few organs which could be regarded insensible, were we aware of the precise circumstances under which their sensibility is elicited. The old doctrine—as old indeed as Hippocrates[1]—was, that the tendons and other membranous parts are among the most sensible of the body. This opinion was implicitly credited by Boerhaave, and his follower Van Swieten;[2] and in many cases had a decided influence on surgical practice more especially. As the bladder consists principally of membrane, it was agreed for ages by lithotomists, that it would be improper to cut or divide it; and, therefore, to extract the stone dilating instruments were used, which caused the most painful lacerations of the parts. Haller[3] considered tendons, ligaments, periosteum, bones, meninges of the brain, different serous membranes, arteries and veins, entirely insensible; yet we know, that they are exquisitely sensible when attacked with inflammation. One of the most painful affections to which man is liable is the variety of whitlow that implicates the periosteum; and in all affections of the bone which inflame or press forcibly upon that membrane, there is excessive sensibility. It would appear, that the possession of vessels or vascularity is a necessary condition of the sensibility of any tissue.

Many parts, too, are affected by special irritants; and, after they have appeared insensible to a multitude of agents, show great sensibility when a particular irritant is applied. Bichat endeavoured to elicit the sensibility of ligaments in a thousand ways, and without success; but when he subjected them to distension or twisting, they immediately gave evidence of it. It is obvious, that before we determine that a part is insensible, it must have been submitted to every kind of irritation. M. Adelon affirms, that there is no part but what may become painful by disease. From this assertion the cuticle might be excepted. If we are right, indeed, in our view of its origin and uses, as described hereafter, sensibility would be of no advantage to it; but the contrary. In the present state, then, of our knowledge, we are justified in asserting, that bones, cartilages, and membranes are not sensible to ordinary external irritants, when in a state of health,—or in other words, that we are not aware of the irritants, which are adapted to elicit their sensibility.

That sensibility is due to the nerves distributed to a part is so generally admitted as not to require comment. Dr. Todd[4] has affirmed, that the anatomical condition necessary for the developement of the greater or less sensibility in an organ or tissue is the distribution in it of a greater or less number of sensitive nerves; and that the anatomist can determine the degree to which this property is enjoyed by any

[1] Foësii Œconom. Hippocr. "Νεῦρον."

[2] Aphorism. 164, and 165, and Comment.

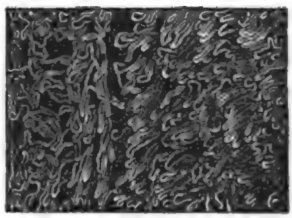
[3] Oper. Minor., tom. i.

[4] Art. Sensation, Cyclopedia of Anat. and Physiology, pt. xxxiv. p. 511, Jan., 1849.

tissue or organ by the amount of nervous supply, which his research discloses. It may well be doubted, however, whether such sensibility be by any means in proportion to the number of nerves received by a part. Nay, some parts are acutely sensible in disease into which nerves cannot be traced. To explain these cases, Reil[1] supposed that each nerve is surrounded at its termination by a nervous atmosphere, by which its action is extended beyond the part in which it is seated. This opinion is a mere creation of the imagination. We have no evidence of any such atmosphere; and it is more philosophical to presume, that the reason we do not discover nerves may be owing to the imperfection of our vision.

We may conclude, that the action of impression occurs in the nerves of the part to which the sensation is referred. As to the mode in which this impression affects them we are ignorant. Microscopic examination of the nerves connected with sensory organs would seem to show, that they come into relation with a substance very analogous to the gray matter of the encephalon, although its elements are somewhat differently arranged. The nervous fibres, too, appear to terminate in close approximation with a vascular plexus; and a granular structure is present, which—as in the cortical portion of the brain—seems to be intermediate. This point has been regarded as the origin of the afferent fibres; and as the seat of changes made by external impressions.[2]

Fig. 33.



Distribution of Capillaries at the surface of the skin of the finger.

The facts mentioned show, that the action of perception takes place in the encephalon; and that the nerve is merely the conductor of the impression between the part impressed and that organ. If a ligature be put round a nerve, sensation is lost below the ligature; but it is uninjured above it. If two ligatures be applied, sensibility is lost in the portion included between the ligatures; but it is restored if the upper ligature be removed. The spinal marrow is sensible along the whole of its posterior column, but it also acts only as a conductor of the impression. M. Flourens destroyed the spinal cord from below, by slicing it away; and found, that sensibility was gradually extinguished in the parts corresponding to the destroyed medulla, but that the parts above evidently continued to feel. Perception, therefore, occurs in the encephalon; and not in the whole, but in some of its parts. Many physiologists—Haller, Lorry, Rolando, and Flourens[3]—sliced away the brain, and found that the sensations continued until the knife reached the level of the corpora quadrigemina; and, again, it has been found, that if the spinal cord be sliced away from below upwards, the sensations persist until we reach the medulla oblongata.

[1] Exercitat. Anatom. Fascic., i. p. 28, and Archiv. für die Physiologie, B. iii.
[2] Carpenter, Human Physiology, p. 85, Lond., 1842.
[3] Rolando, Saggio sopra la vera Struttura del Cervello, Sassari, 1809; and Flourens, Recherches Expérimentales sur les Propriétés et les Fonctions du Système Nerveux, &c., 2de édit., Paris, 1842.

It is, then, between these parts, that we must place the cerebral organs of the senses, and it is with this part of the cephalo-spinal axis, that the nerves of the senses are actually found to communicate. Mr. Lawrence[1] saw a child with no more encephalon than a bulb, which was a continuation of the medulla spinalis, for about an inch above the foramen magnum, and with which all the nerves from the fifth to the ninth pair were connected. The child's breathing and temperature were natural; it discharged urine and fæces; took food, and at first moved very briskly. It lived four days.

If we divide the posterior roots of the spinal nerves and the fifth pair, *general* sensibility is lost; but if we divide the nerves of the senses, we destroy only their functions. We can thus understand why, after decapitation, sensibility may remain for a time in the head. It is instantly destroyed in the trunk, owing to the removal of all communication with the encephalon; but the fifth pair is entire, as well as the nerves of the organs of the senses. Death must of course follow almost instantaneously from loss of blood; but there is doubtless an appreciable interval during which the head may continue to feel; or, in other words, during which the external senses may act.[2] M. Julia Fontanelle[3] has indeed concluded, from a review of all the observations made on this matter, that, contrary to the common opinion, death by the guillotine is one of the most painful; that the pains of decollation are horrible, and endure even until there is an entire extinction of animal heat! It need scarcely be said, that all these inferences are imaginative, and perhaps equally fabulous with the oft-told story of Charlotte Corday scowling at the executioner after her head was removed from her body by the guillotine; and this conclusion is strongly confirmed by the results of experiments on a robber—who was beheaded with the sword—by Drs. Bischoff, Heerman, and Jolly, who inferred that consciousness must have ceased instantaneously.[4] But if such be the case with man, it most assuredly is not so with the inferior animals. Ample evidence will be afforded hereafter to show, that both sensation and volition may persist in the rattlesnake and alligator long after the head has been removed from the body. Singular facts in regard to the latter animal have been recorded by Dr. Leconte,[5] and more recently, by Dr. Dowler,[6] of New Orleans.

It has been remarked, that the cerebral hemispheres may be sliced away without abolishing the senses. The experiments of Rolando and Flourens, which have been repeated by M. Magendie, show, however, that the sight is an exception;—that it is lost by their removal. If the right hemisphere be sliced away, the sight of the left eye is lost; and conversely;—one of the facts that prove the decussation of the optic

[1] Medico-Chirurg. Transact., v. 166.

[2] Bérard, Rapports du Physique et du Moral, p. 93, Paris, 1823.

[3] Phœbus, Art. Enthauptung, in Encyclopäd. Wörterb. der Medicin. Wissenchaft. xi. 204, Berlin, 1835.

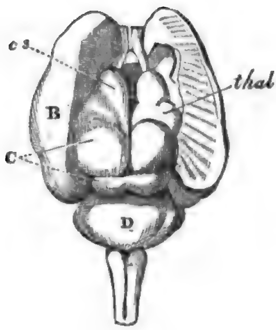
[4] A condensed account of Dr. Bischoff's Remarks, from Müller's Archiv., by S. L. L. Bigger, is in the Dublin Journal of Medical Science, Sept., 1839, p. 1.

[5] New York Journal of Medicine, for Nov., 1845, p. 335, and Sir Charles Lyell, Travels in North America, Amer. edit., i. 237. New York, 1849.

[6] Contributions to Physiology, New Orleans, 1849, from New Orleans Journal of Medicine.

nerves. The experiments of these gentlemen show, that vision, more than the other senses, requires a connexion with the organ of the intellectual faculties—the cerebral hemispheres; and this, as M. Magendie has ingeniously remarked, because vision rarely consists in a single impression made by light, but is connected with an intellectual process, by which we judge of the distance, size, shape, &c., of bodies. It has been well suggested and maintained by Dr. Carpenter,[1] that whilst the cerebral ganglia are the organs of the higher intellectual and moral acts; there is a series of ganglia, connected with the reception of impressions from without, which are seated near the base of the brain, and are hence termed by him *sensory ganglia.* As we descend in the animal scale, these ganglia become more marked; whilst the cerebral hemispheres become less and less; until ultimately the animal appears to have its encephalic organs limited almost wholly to those that are concerned in the reception of impressions from without, and the originating of motor impulsions from within. These ganglia are seated at the base of the brain: from the origin of the auditory nerves to those of the olfactory.

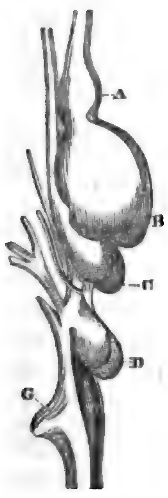
Fig. 34.



Brain of Squirrel, laid open.

The hemispheres, B, drawn to either side to show the subjacent parts. C. The optic lobes. D. Cerebellum. *thal.* Thalamus opticus. *c s.* Corpus striatum.

Fig. 35.



Brain of Turtle.

A. Olfactive ganglia. B. Cerebral hemispheres. C. Optic ganglia. D. Cerebellum.

Fig. 36. Pike.

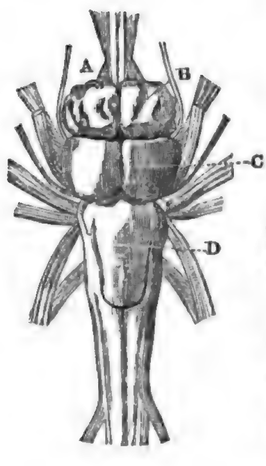
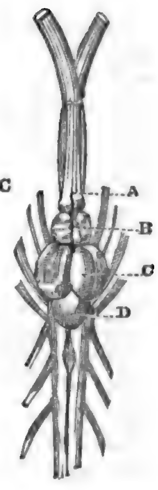


Fig. 37. Cod.



Brains of Fishes.

A. Olfactive lobes or ganglia. B. Cerebral hemispheres. C. Optic lobes. D. Cerebellum.

Dr. Carpenter is disposed to regard the optic thalami as ganglia for the reception of tactile impressions, and the corpora striata as ganglia con-

[1] Principles of Human Physiology, 4th Amer. edit., p. 370, Philad., 1850.

nected with motion. He esteems them to be, moreover, the centre of consensual or instinctive movements, or of automatic movements involving sensation;—a topic which will receive attention elsewhere.

Having arrived at a knowledge that in man and the upper class of animals, perception is effected in a part of the encephalon, our acquaintance with this mysterious process ends. We know not, and we probably never shall know, the action of the brain in accomplishing it. It is certainly not allied to any physical phenomenon; and if we are ever justified in referring functions to the class of *organic* and *vital*, it may be those, that belong to the elevated phenomena, which have to be considered under the head of animal functions. We know them only by their results: yet we are little better acquainted with many topics of physical inquiry;—with the nature of the electric fluid for example.

The organs, then, that form the media of communication between the parts impressed and the brain, are the nerves and spinal marrow. M. Broussais,[1] indeed, affirmed, that every stimulation capable of causing perception in the brain, runs through the whole of the nervous system of relation; and is repeated in the mucous membranes, whence it is again returned to the centre of perception, which judges of it according to the view of the viscus to which the mucous membrane belongs; and adapts its action as it perceives pleasure or pain.

We are totally unacquainted with the *material* character of the fluid, which passes with the rapidity of lightning along nervous cords; and it is as impossible to describe its mode of transmission, as it is to depict that of the electric fluid along a conducting wire. As in the last case, we are aware of such transmission only by the result. Still, hypotheses, as on every obscure matter of inquiry, have not been wanting.[2] Of these, three are chiefly deserving of notice. The *first*, of greatest antiquity, is, that the brain secretes a subtile fluid, which circulates through the nerves, called *animal spirits*, and which is the medium of communication between the different parts of the nervous system; the *second* regards the nerves as cords, and the transmission as effected by means of the vibrations or oscillations of these cords; whilst the *third* ascribes it to the operation of electricity.

1. The hypothesis of *animal spirits* has prevailed most extensively. It was the doctrine of Hippocrates, Galen, the Arabians, and of most of the physicians of the last centuries. Des Cartes[3] adopted it energetically; and was the cause of its more extensive diffusion. The great grounds assigned for the belief were;—*first*, that as the brain receives so much more blood than is necessary for its own nutrition, it must be an organ of secretion; *secondly*, that the nerves seem to be a continuation of the tubular matter of the brain; and it has already been remarked, that Malpighi considered the cortical neurine to be follicular, and the medullary to consist of secretory tubes. It was not unnatural, therefore, to regard the nerves as vessels for the transmission of these spirits. As, however, the animal spirits had never been met with in a

[1] Traité de Physiologie, &c., Paris, 1822; or translation by Drs. Bell and La Roche, 3d Amer. edit., p. 63, Philad., 1832.

[2] Fletcher's Rudiments of Physiology, P. ii. *b.* p. 68, Edinb., 1836.

[3] Tractatus de Homine, p. 17, Lugd. Bat., 1664.

tangible shape, ingenuity was largely invoked in surmises regarding their nature; and, generally, opinions settled down into the belief that they were of an ethereal character. For the various views that have been held upon the subject, the reader is referred to Haller,[1] who was himself an ardent believer in their existence, and has wasted much time and space in an unprofitable inquiry into their nature. The truth is, that we have not sufficient evidence, direct or indirect, of the existence of any nervous fluid of the kind described. Allusion has been already made to the views, in regard to the tubular structure of the white neurine, admitted by most observers: Berres,[2] affirms that the forms, which the nervous substance assumes under the magnifying glass, can only be compared to those of canals and vesicles; but whether they be hollow he does not attempt to decide. M. Raspail[3] has concluded, that the opinion of their being hollow, and containing a fluid, is unsupported by facts; for although he admits, that M. Bogros succeeded in injecting the nerves with mercury, he thinks that the passage of the metal along them was owing to its having forced its way by gravity. Modern histologists accord with great unanimity as to the tubular structure of the medullary neurine; but we have no reason for considering the brain the organ of any ponderable secretion. Yet the term "animal spirits," although their existence is not now believed, is retained in popular language. We speak of a man who has a great flow of animal spirits, but without regarding the hypothesis whence the expression originated.

The term *nervous fluid* is still used by physiologists. By this, however, they simply mean the medium of communication or of conveyance, by which the nervous influence is carried with the rapidity of lightning from one part of the system to another; but without committing themselves as to its character;—so that, after all, the idea of animal spirits is in part retained, although the term, as applied to the nervous fluid is generally exploded. Dr. Good[4] directly admits them under the more modern title; Mr. J. W. Earle[5] firmly believes in the existence of a circulation in the nervous system,—and it is not easy to conceive, that the brain does not possess the function of elaborating some fluid,—galvanoid or other,—which is the great agent in the nervous function.

2. The hypothesis of vibrations is ancient, but has been by no means as generally admitted as the last. Among the moderns, it has received the support of Condillac,[6] Hartley,[7] Blumenbach,[8] and others; some supposing, that the nervous matter itself is thrown into vibrations; others, that an invisible and subtile ether is diffused through it, which acts the sole or chief part. As the latter is conceived, by many, to be the mode in which electricity is transmitted along conducting wires,

1 Elementa Physiologiæ, x. 8.

2 Oesterreich. Med. Jahrbuch., B. ix., cited in Brit. and Foreign Med. Review, January, 1838, p. 219.

3 Chimie Organique, p. 218. Paris, 1833.

4 Study of Medicine, with Notes by S. Cooper, Doane's Amer. edit., vol. ii., in Proem to Class iv. Neurotica, New York, 1835.

5 New Exposition of the Functions of the Nerves, by James William Earle, Part I. London, 1833.

6 Œuvres, Paris, 1822.

7 Observations on Man, &c., chap. i. sect. 1. London, 1791.

8 Institutiones Physiologicæ, § 226.

it is not liable to the same objections as the former. Simple inspection, however, of a nerve at once exhibits, that it is incapable of being thrown into vibrations. It is soft; never tense; always pressed upon in its course; and, as it consists of filaments destined for very different functions,—sensation, voluntary and involuntary motion, &c.—we cannot conceive how one of these filaments can be thrown into vibration without the effect being extended laterally to others; and great confusion being thus induced. The view of Dr. James Stark[1] in regard to the structure of the tubes of the nerves, has led him to adopt a modification of the theory of vibrations. Believing, that the matter which fills the tubes is of an oily nature,—and as oily substances are known to be non-conductors of electricity; and farther, as the nerves have been shown by the experiments of Bischoff to be amongst the worst possible conductors of electricity,—he contends, that the nervous energy can be neither electricity nor galvanism, nor any property related to them; and he conceives, that the phenomena are best explained on the hypothesis of undulations or vibrations propagated along the course of the tubes by the oily globules they contain.

3. The last hypothesis is of later date,—subsequent to the discoveries in animal electricity. The rapidity with which sensation and volition are communicated along the nerves, could not fail to suggest a resemblance to the mode in which the electric and galvanic fluids fly along conducting wires. Yet the great support of the opinion was in the experiments of Dr. Wilson Philip[2] and others, from which it appeared, that if the nerve proceeding to a part be destroyed,—and the secretion, which ordinarily takes place in the part be thus arrested,—the secretion may be restored by causing the galvanic fluid to pass from one divided extremity of the nerve to the other. The experiments, connected with secretion, will be noticed more at length hereafter. It will likewise be shown, that in the effect of galvanism upon the muscles, there is a like analogy;—that the muscles may be made to contract for a length of time after the death of the animal, and even when a limb is removed from the body, on the application of the galvanic stimulus; whilst comparative anatomy exhibits to us great development of nervous structure in electrical animals, which astonish us by the intensity of the electric shocks they are capable of communicating.

Physiologists of the present day generally, we think, accord with the electrical hypothesis. The late Dr. Young,[3] so celebrated for his knowledge in numerous departments of science, adopted it prior to the interesting experiments of Dr. Philip; and Mr. Abernethy,[4] whilst he is strongly opposing the doctrines of materialism, goes so far as to consider some subtile fluid not merely as the agent of nervous transmission, but as forming the essence of life itself. By putting a ligature, however, around a nervous trunk, its functions, as a conductor of nervous influence, are paralyzed, whilst it is still capable

[1] Proceedings of the Royal Society, No. 56, Lond., 1843.
[2] Philosoph. Trans. for 1815, and Lond. Med. Gazette for March 18, and March 25, 1837.
[3] Med. Literature, p. 93. Lond., 1813.
[4] Physiological Lectures, exhibiting a view of Mr. Hunter's Physiology, &c. Lond., 1817.

of conveying electricity; and, moreover, when wires are inserted into an exposed nerve, and their opposite extremities are attached to the galvanometer, no movement of the needle has been observed by Person, Müller, Matteucci, and by Todd and Bowman.[1] Dr. Bostock,[2] too, has remarked, that before the electrical hypothesis can be considered proved, two points must be demonstrated; first, that *every* function of the nervous system may be performed by the substitution of electricity for the action of nerves; and secondly, that *all* nerves admit of this substitution. This is true, as concerns the belief in the *identity* of the nervous and electrical fluids; but we have, even now, evidence sufficient to show their similarity; and that we are justified in considering the nervous fluid to be electroid or galvanoid in its nature, emanating from the brain by some action unknown to us, and transmitted to the different parts of the system to supply the expenditure, which must be constantly taking place.

Reil,[3] Senac,[4] Prochaska, Scarpa,[5] and others are of opinion, that the nervous agency is generated throughout the nervous system; and that every part derives sensation and motion from its own nerves. We have satisfactorily shown, however, that a communication with the nervous centres is absolutely necessary in all cases, and that we can immediately cut off sensation in the portion of a nerve included between two ligatures, and as instantly restore it by removing the upper ligature, and renewing the communication with the brain.

a. External Sensations.

The external sensations are those perceptions which are occasioned by the impressions of bodies external to the part impressed. They are not confined to impressions made by objects external to us. The hand applied to any part of the body; any two of its parts brought into contact; the presence of its own secretions or excretions may equally excite them. M. Adelon,[6] has divided them into two orders—*first*, the *senses*, properly so called, by the aid of which the mind acquires its notion of external bodies, and of their different qualities; and *secondly*, those sensations which are still caused by the contact of some body; and yet afford no information to the mind.

It is by the external senses, that we become acquainted with the bodies that surround us. They are the instruments by which the brain receives its knowledge of the universe; but they are only instruments, and cannot be considered as the sole regulators of the intellectual sphere of the individual. This we shall see is dependent upon another and still higher nervous organ,—the brain.

The external senses are generally considered to be five in number; for, although others have been proposed, they may perhaps be reduced to some modification of these five,—*tact* or *touch*, *taste*, *smell*, *hearing*,

[1] The Physiological Anatomy and Physiology of Man, p. 242. Lond., 1845.
[2] An Elementary System of Physiology, 3d edit., p. 148. Lond., 1836.
[3] De Structurâ Nervorum, Hal., 1796.
[4] Traité de la Structure du Cœur, &c., liv. iv. chap. 8. Paris, 1749.
[5] Tabulæ Neurologicæ. Ticin., 1794, § 22.
[6] Physiologie de l' Homme, tom. i. p. 259, 2de édit. Paris, 1829.

and *vision*. All these have some properties in common. They are situate at the surface of the body, so as to be capable of being acted upon with due facility by external bodies. They all consist of two parts: —the one, *physical*, which modifies the action of the body, that causes the impression; the other *nervous* or *vital*, which receives the impression, and conveys it to the brain. In the eye and the ear, we have better exemplifications of this distinction than in the other senses. The physical portion of the eye is a true optical instrument, which modifies the light, before it impinges upon the retina. A similar modification is produced by the physical portion of the ear on the sonorous vibrations, before they reach the auditory nerve; whilst in the other senses, the physical portion forms a part of the common integument in which the nervous portion is seated, and cannot be easily distinguished. Some of them, again, as the skin, tongue, and nose, are symmetrical, that is, composed of two separate and similar halves, united at a median line. Others, as the eye and ear, are in pairs; and this, partly perhaps, to enable the distances of external objects to be appreciated. We shall find, at least, that there are certain cases, in which both the organs are necessary for accurate appreciation.

Two of the senses—vision and audition—have, respectively, a nerve of special sensibility; and, until of late years, the smell has been believed to be similarly situate. In the present state of our knowledge, we cannot decide upon the precise nerve of taste, although it will be seen that a plausible opinion may be indulged on the subject. The general sense of touch or feeling is certainly seated in the nerves of general sensibility connected with the posterior roots of the spinal nerves and the fifth encephalic pair; and according to some,[1] in the glosso-pharyngeal and pneumogastric nerves. The other senses seem intimately connected with one nerve of general sensibility,—the fifth pair. This is especially the case with those senses that possess nerves of special sensibility; for, if the fifth pair be cut, the function is abolished or impaired, although the nerve of special sensibility may remain entire.

Being instruments by which the mind becomes acquainted with external bodies, it is manifestly of importance, that the senses should be influenced by volition. Most of them are so. The touch has the pliable upper extremity, admirably adapted for the purpose. The tongue is movable in almost every direction. The eye can be turned by its own immediate muscles towards objects in almost all positions. The ear and the nose possess the least individual motion; but the last four, being seated in the head, are capable of being assisted by the muscles adapted for its movements.

All the senses may be exercised *passively* and *actively*. By directing the attention, we can render the impression more vivid; and hence the difference between simply seeing or passive vision, and looking attentively; between hearing and listening; smelling and snuffing; touching and feeling closely. It is to the active exercise of the senses, that we are indebted for many of the pleasures and comforts of social existence. Yet, to preserve the senses in the vigour and delicacy,

[1] Longet, Traité de Physiologie, ii. 176, note. Paris, 1850.

which they are capable of acquiring by attention, the impressions must not be too constantly or too strongly made. The occasional use of the sense of smell, under the guidance of volition, may be the test on which the chemist, perfumer, or wine-merchant, may rely in the discrimination of the numerous odorous characteristics of bodies; but, if the olfactory nerves be constantly, or too frequently, stimulated by excitants, of this or any other kind, dependence can no longer be placed upon them as a means of discrimination. The maxim that "habit blunts feeling," is true only in such cases as the last. Education can, indeed, render it extremely acute.[1] Volition, on the other hand, enables us to deaden the force of sensations. By corrugating the eyebrows and approximating the eyelids, we can diminish the quantity of light when it is too powerful. We can breathe through the mouth, when a disagreeable odour is exhaled around us; or can completely shut off its passage by the nostrils, with the aid of the upper extremity. Over the hearing we have less command as regards its individual action: the upper extremity is here always called into service, when we desire to diminish the intensity of any sonorous impression.

Lastly. It is a common observation, that the loss of one sense occasions greater vividness in others. This is only true as regards the senses that administer chiefly to the intellect,—those of touch, audition, and vision, for example. Those of smell and taste may be destroyed; and yet the more intellectual senses may be uninfluenced. In the singular condition of artificial somnambulism or hypnotism, the author has seen the various senses rendered astonishingly acute.

The cause of the superiority of the remaining intellectual senses, when one has been lost, is not owing to any superior organization in those senses; but is another example of the influence of education. The remaining senses are exerted attentively to compensate for the privation; and they become surprisingly delicate.

We proceed to the consideration of the separate senses, beginning with that of *tact* or *touch*, because it is most generally distributed, and may be regarded as that from which the others are derived. They are all, indeed, modifications of the sense of touch. In the taste, the sapid body; in the smell, the odorous particle; in the hearing, the sonorous vibration; and in the sight, the particle of light, must impinge upon or *touch* the nervous part of the organ, before sensation can, in any of the cases, be effected.

SENSE OF TACT OR TOUCH—PALPATION.

The sense of tact or touch is the general feeling or sensibility, possessed by the skin especially, which instructs us regarding the temperature and general qualities of bodies. By some, touch is restricted to the sense of resistance alone; and hence they have conceived it necessary to raise into a distinct sense one of the attributes of tact or touch. The sense of heat, for example, has been separated from tact; but although the appreciation of external bodies by tact or touch differs

[1] Bérard, Rapport du Physique et du Moral, p. 245; Paris, 1823.

—as will be seen—in some respects from our appreciation of their temperature, its consideration properly belongs to the sense we are considering, in the acceptation here given to it, and adopted by all the French physiologists. According to them, tact is spread generally in the organs, and especially in the cutaneous and mucous surfaces. It exists in all animals; whilst touch is exercised only by parts evidently destined for that purpose, and is not present in every animal. It is nothing more than tact joined to muscular contraction and directed by volition. So that, in the exercise of tact, we may be esteemed *passive;* in that of touch, *active.*

The organs concerned in touch, execute other functions besides; and in this respect touch differs from the other senses. Its chief organ, however, is the skin; and hence it is necessary to inquire into its structure, so far as is requisite for our purpose.

1. ANATOMY OF THE SKIN, HAIR, NAILS, ETC.

The upper classes of animals agree in possessing an outer envelope or skin, through which the insensible perspiration passes; a slight degree of absorption takes place; the parts beneath are protected; and the sense of touch is accomplished. In man, the skin is generally considered to consist of four parts,—the cuticle, rete mucosum, corpus papillare, and corium; but when reduced to its simplest expression, the whole of the integument, with the mucous membrane, which is an extension of it, may be regarded as a continuous membrane, more or less involuted, more or less modified by the elementary tissues which compose it or are in connexion with it, and within which all the rest of the animal is contained. It consists of two elements—a *basement tissue* or *membrane*, composed of simple membrane, uninterrupted, homogeneous, and transparent; covered by an *epithelium* or pavement of nucleated particles.[1]

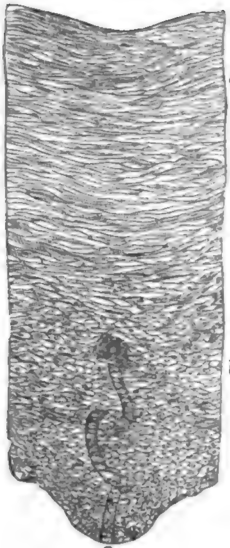
1. The *epidermis* or cuticle is the outermost layer. It is a dry, membranous structure, devoid of vessels and nerves; yet it is described by some recent investigators as a tissue of a somewhat complex organization, connected with the functions of exhalation and absorption; but its vitality is regarded to be on a par with that of vegetables. The absence of nerves proper to it renders it insensible; it is coloured; and exhales and absorbs in the manner of vegetables. It is, so far as we know, entirely insensible; resists putrefaction for a long time, and may be easily obtained in a separate state from the other layers by maceration in water. It is the thin pellicle raised by a blister.

The cuticle is probably a secretion or exudation from the true skin, which concretes on the surface; becomes dried, and affords an efficient protection to the corpus papillare beneath. It is composed, according to some, of concrete albumen; according to others, of mucus; and is pierced by oblique pores for the passage of hairs, and for the orifices of exhalant and absorbent vessels. MM. Breschet and Roussel de Vauzème[2] affirm, that there is a special "*blennogenous* or *mucific apparatus*" for

[1] Todd and Bowman, The Physiological Anatomy and Physiology of Man, p. 404, London, 1845.
[2] Nouvelles Recherches sur la Structure de la Peau, par M. Breschet, Paris, 1835.

the secretion of this mucous matter, composed of a glandular parenchyma or organ of secretion situate in the substance of the derma, and

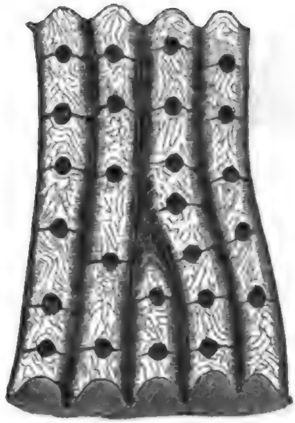
Fig. 38.



Vertical Section of Epidermis, from Palm of the Hand.

a. Outer portion, composed of flattened scales. *b*. Inner portion, consisting of nucleated cells. *c*. Tortuous perspiratory tube, cut across by the section higher up. —Magnified 155 diameters.

Fig. 39.



Surface of the Skin of the Palm, showing the Ridges, Furrows, Cross-grooves, and Orifices of the Sweat-ducts.

The scaly texture of the cuticle is indicated by the irregular lines on the surface.—Magnified 20 diameters.

of excretory ducts, which issue from the organ, and deposit the mucous matter between the papillæ; but such an apparatus is not usually admitted.

It is probable, that the cuticle is placed at the surface of the body, not simply to protect the corpus papillare; but to prevent the constant imbibition and transudation that might take place did no such envelope exist. It exfoliates, in the form of scales, from the head; and in large pieces, from every part of the body, after certain cutaneous diseases.

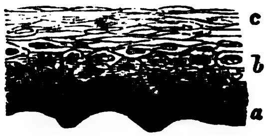
M. Flourens,[1] who has closely and accurately investigated the anatomy of the cutaneous envelope, considers that the skin of the coloured races has an apparatus, which is wanting in the white variety of the species. This apparatus he names pigmental,—*appareil pigmental.* It is composed of a layer (*lame*) or membrane which bears the pigment, and of the pigment itself. Above it are two cuticles. In the white variety the pigmental apparatus is wanting, and consequently the skin is more simple than that of the coloured races. The skin of the white variety approaches that of the coloured in some remarkable points. *First.*—The superficial layer or *lame* of the derma is everywhere of a peculiar appearance, which is different from that of the

[1] Anatomie Générale de la Peau et des Membranes Muqueuses, p. 34, Paris, 1843.

rest of the derma. *Secondly.*—Around the nipple of the white woman, the superficial layer of the derma presents the same granular appearance as the *pigmental membrane* of the coloured races. And *thirdly.*—The *pigmental layer* around the nipple of the white woman is placed, as in the coloured races, under the two cuticles.

Modern histologists consider the epidermis to be composed of a series of flattened, scale-like cells, *epidermic cells*, which, when first formed, are of a spheroidal shape; but gradually dry up. These form various layers. According to M. Raspail,[1] it consists of a collection of vesicles deprived of their contents, closely applied together, dried, and thrown off in the form of branny scales. He regards it as the outer layer of the corium.

Fig. 40.



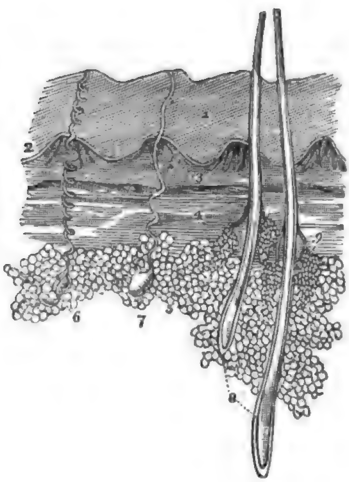
Vertical Section of the Cuticle from the Scrotum of a Negro.

a. Deep cells, loaded with pigment. *b*. Cells at a higher level, paler and more flattened. *c*. Cells at the surface, scaly and colourless as in the white races.—Magnified 300 diameters.

The epidermoid tissues have the simplest structure of any solids.

Analysis has shown, that the chemical constitution of the membranous epidermis of the sole of the foot is the same as that of the compact horny matter of which nails, hair, and wool are composed.

Fig. 41.



Section of the Skin.

1. Cuticle, showing the oblique laminæ of which it is composed and the imbricated disposition of the ridges upon its surface. 2. Rete mucosum. 3. Two of the quadrilateral papillary masses seen in the palm of the hand or sole of the foot; they are composed of minute conical papillæ. 4. Deeper layer of the cutis, the corium. 5. Adipose vesicles; showing their appearance beneath the microscope. 6. Perspiratory gland with its spiral duct, as seen in the palm of the hand or sole of the foot. 7. Another perspiratory gland with a straighter duct, such as seen in the scalp. 8. Two hairs from the scalp, enclosed in their follicles; their relative depth in the skin preserved. 9. A pair of sebaceous glands opening by short ducts into the follicle of the hair.

2. The *corpus* or *rete mucosum*, *rete Malpighii*, *mucous web*, is generally regarded as constituting the next layer. It was considered by Malpighi to be mucus, secreted by the papillæ, and spread on the surface of the corpus papillare, to preserve it in the state of suppleness necessary for the performance of its functions. In this rete mucosum, the colouring matter of the dark races seems to exist. It is black in the African, or rather in the Ethiopian; and copper-coloured in the mulatto.[2] Gaultier[3] considers it to be composed of four layers; but this notion is not admitted by anatomists, and scarcely concerns the present inquiry. M. Breschet affirms, that there is a special "*chromatogenous* or *colorific apparatus*," for producing the colouring

[1] Chimie Organique, p. 245, Paris, 1833.
[2] Sir E. Home, Lect. on Comp. Anat., v. 278.
[3] Recherches Anatomiques sur le Système Cutané de l'Homme, Paris, 1811.

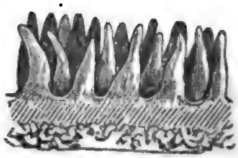
matter, composed of a glandular or secreting parenchyma, situate a little below the papillæ, and presenting special excretory ducts, which pour out the colouring matter on the surface of the derma.

Modern observers deny, that there is any such distinct layer. Some regard it as the deepest or most recently formed part of the cuticle. M. Flourens[1] considers, that the term corpus mucosum ought to be replaced by that of pigmental apparatus,—*appareil pigmental;* and that the term *rete* or *corpus reticulare* in the signification of a special network situate between the derma and the two cuticles, ought to be banished from anatomy. The nature of the pigment will be referred to hereafter, under SECRETION.

The rete mucosum is considered to be the last formed portion of the cuticle.

3. The *corpus papillare*, or what M. Breschet calls the "*neurothelic* or *mammillary nervous apparatus*," is seated next below the rete mucosum. It consists of a collection of small papillæ, formed by the extremities of nerves and vessels, which, after having passed through the corium beneath, are grouped in small pencils or villi on a spongy, erectile tissue. These pencils are disposed in pairs, and, when not in action, are relaxed, but become erect when employed in the sense of touch. They are very readily seen, when the cutis vera is exposed by the action of a blister; and are always evident at the palmar surface of the hand, and especially at the tips of the fingers, where they have a concentric arrangement. These villi are sometimes called *papillæ*. They are, in reality, prolongations of the skin; and consequently—as M. Flourens[2] has remarked—"the pretended *corpus papillare*, taken as a body, apart and distinct from the derma, is but an idle name."

Fig. 42.



Papillæ of the palm, the Cuticle being detached.—Magnified 35 diameters.

4. The *corium, cutis vera, derma, true skin*, is the innermost layer of the skin. It consists of a collection of dense fibres, intersecting each other in various directions; and leaving between them holes for the passage of vessels and nerves. It forms a firm stratum, giving the whole skin the necessary solidity for accomplishing its various ends; and consists chiefly of gelatin;—hence it is used in the manufacture of glue. Gelatin, when united with tannic acid, forms a substance which is insoluble in water; and it is to this combination that leather owes the properties it possesses. The hide is first macerated in lime-water to remove the cuticle and hairs, and leave the corium or gelatin. This is then placed in an infusion of oak bark, which contains tannic acid. The tannic acid and the skin unite; and leather is the product.

These four strata constitute the *skin*, as it is commonly called; yet all are comprised in the thickness of two or three lines. The cutis vera is united to the structures below by areolar tissue; and this, with

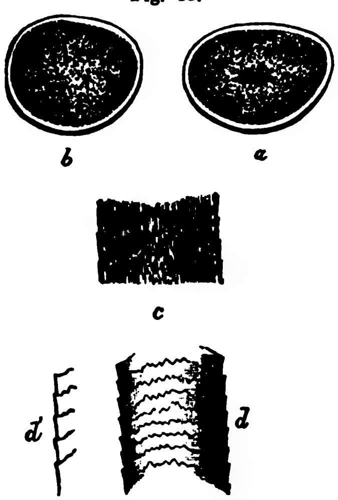
[1] Op. cit., p. 38.

[2] Op. cit., p. 38.

the layers external to it, forms the *common integument.* In certain parts of the body, and in animals more particularly, the cutis vera is adherent to muscular fibres, inserted more or less obliquely. These form the *muscular web*, *mantle* or *panniculus carnosus.* The layer is well seen in the hedge-hog and porcupine, in which it rolls up the body, and erects the spines; and in birds, raises the feathers. In man, it can hardly be said to exist. Some muscles, however, execute a similar function. By the occipito-frontalis, many persons can move the hairy scalp; and by the dartos the skin of the scrotum can be corrugated. These two parts, therefore, act as *panniculi carnosi.*

In the skin are situate numerous *sebaceous follicles* or *crypts*, which separate an oily fluid from the blood, and pour it over the surface to lubricate and defend it from the action of moisture. They are most abundant, where there are folds of the skin, or hairs, or where the surface is exposed to friction. We can generally see them on the pavilion of the ear, and their situation is often indicated by small dark spots on the surface, which, when pressed between the fingers, may be forced out along with the sebaceous secretion, in the form of small worms. By the vulgar, indeed, these are considered to be worms. The follicular secretions will engage attention hereafter.

Fig. 43.



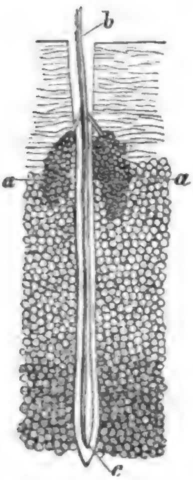
Sections of Hair.

a. Transverse section of a hair of the head, showing the exterior cortex, the medulla or pith with its scattered pigment, and a central space filled with pigment. *b.* A similar section of a hair, at a point where no aggregation of pigment in the axis exists. *c.* Longitudinal section, without a central cavity, showing the imbrication of the cortex, and the arrangement of the pigment in the fibrous part. *d.* Surface, showing the sinuous transverse lines formed by the edges of the cortical scales. *d'.* A portion of the margin, showing their imbrication.—Magnified 150 diameters. (Todd and Bowman.)

The consideration of the *hair* belongs naturally to that of the skin. The roots are in the form of bulbs; taking their origin in small follicles or open sacs, *hair follicles*, formed by the inversion of the cutis, and lined by a reflexion of the epidermis. Around each bulb there are two capsules, the innermost of which is vascular and a continuation of the corium. The hair itself consists of a horny, external covering, and a central part, called *medulla* or *pith.* When we take hold of a hair by the base, with the thumb and forefinger, and draw it through them from the root towards the point, it feels smooth to the touch; but if we draw it through from the point to the root, we feel the surface rough; and it offers considerable resistance. It is, therefore, concluded, that the hair is bristled, imbricated or consists of eminences pointing towards its outer extremity, and it is upon this structure, that the operation of felting is dependent—the hairs being mechanically entangled and retained in that state by the inequalities of their surface. Certain observers have, however, failed in detecting this striated appearance by the aid

of the microscope; and Dr. Bostock[1] affirms, that he had an opportunity of viewing the human hair, and the hair of various kinds of animals, in the excellent microscope of Mr. Bauer, but without being able to observe

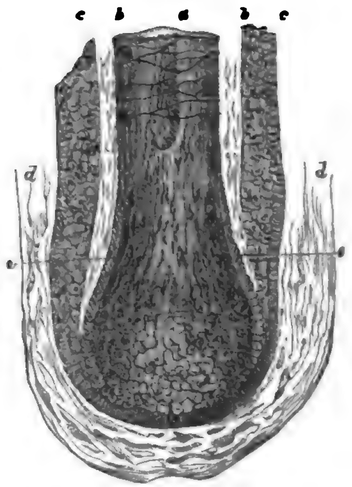
Fig. 44.



Thin Layer from the Scalp.

a, a. Sebaceous glands. *b.* Hair, with its follicle, *c.* (Gurlt.)

Fig. 45.



Magnified view of the Root of the Hair. (Kohlrausch.)

a. Stem or shaft of hair cut across. *b.* Inner, and *c.* Outer layer of the epidermic lining of the hair follicle, called also the root-sheath. *d.* Dermic or external coat of the hair follicle, shown in part. *e.* Imbricated scales about to form a cortical layer on the surface of the hair.

it. Bichat,[2] however, and more recently, Dr. Goring,[3] and most histologists, have assigned this as their structure; and the author has had repeated opportunities for confirming it with his own admirable microscope, made by Smith, of London.

Modern observers believe, that, as in other structures, growth takes place from cells, which are a modification of those of the epidermis. The primary cells become elongated, and generate within themselves fasciculi of fibres or secondary cells, which interlace to form the hair cylinder. The walls of these fibre-cells are at first soft and permeable; and the lower part of the hair, which is composed of them, seems to admit the passage of fluid without much difficulty. At a short distance from the base, the horny character of the hair, caused by the deposit of horny matter in the interior of the fibres, becomes apparent. "There is then, at the base, a continual formation of soft fibrous tissue, by which the length of the cylinder is increased; whilst at a short distance above it, there is a continual consolidation of this (as it progressively arrives at that point) by the deposit of a peculiar secretion in its substance."[4]

[1] Physiology, p. 52, 3d edit., Lond., 1836. [2] Anat. Général., tom. iv., § 2.
[3] Journal of Science, New Series, vol. i. 433.
[4] Carpenter, Human Physiology, § 637. Lond., 1842.

The colour of the hair is different in different races and individuals. By some, this is considered to depend upon the fluids contained in the pith. M. Vauquelin[1] analyzed the hair attentively, and found it to consist chiefly of an animal matter, united to a portion of oil, which appeared to contribute to its flexibility and cohesion. Besides this, there is another substance, of an oily nature, from which he considers the colour of the hair is derived. The animal matter, according to that chemist, is a species of mucus; but other chemists believe it to be chiefly albumen. Vauquelin found, that the colouring matter is destroyed by acids; and he suggests, that when it has suddenly changed colour and become gray, in consequence of any mental agitation, this may be owing to the production of an acid in the system, which acts upon the colouring matter. The explanation is hypothetical, and is considered, and characterized as such by Dr. Bostock; but it must be admitted, that the same objection applies to the view he has substituted for it. He conceives it "more probable that the effect depends upon a sudden stagnation in the vessels, which secrete the colouring matter; while the absorbents continue to act, and remove that which already exists." There is, however, no more real evidence of "stagnation of vessels" than there is of the formation of an acid. Our knowledge is limited to the fact, that a sudden and decided change in the whole pileous system may occur after great or prolonged mental agitation.

> "My hair is gray, but not with years,
> Nor grew it white in a single night,
> As men's have grown from sudden fears."
> *Byron's "Prisoner of Chillon."*
>
> "Danger, long travail, want and wo,
> Soon change the form that best we know:
> For deadly fear can time outgo,
> And blanch at once the hair.
> Hard toil can roughen form and face,
> And want can quench the eye's bright grace,
> Nor does old age a wrinkle trace
> More deeply than despair."
> *Scott's "Marmion."*[2]

It is stated by M. De Lamartine,[3] that such a change occurred in a single night to the queen of Louis the 16th—the unfortunate Marie Antoinette—when the royal party was arrested at Varennes, in 1791.

But a similar, though more gradual change, is produced by age. We find some persons entirely gray at a very early period of life; and, in old age, the change happens universally. It is not then difficult to suppose, that some alteration in the nutrition of the hair may supervene, resembling that which occurs in the progress of life. Dr. Bostock doubts the fact of such sudden conversions; but the instances are too numerous for us to consider them entirely fabulous. Still, it is difficult to comprehend how parts, which, like the extremities of the hair, are

[1] Annales de Chimie, tom. lviii. p. 41, Paris, 1806.

[2] For many such cases see M. E. Wilson, a Practical Treatise on Healthy Skin, p. 95. London, 1845.

[3] "La reine ne dormit pas. Toutes ses passions, de femme, de mère, de reine, la colére, la terreur, la desespoir, se livrèrent un tel assaut dans son âme, que ses cheveux, blonds la vieille, furent blancs le lendemain."—*Histoire des Girondins*, i. 116. Paris, 1847.

foreign to nutrition, can change so rapidly. M. Lepelletier[1] ascribes it to two very different causes. *First*, to defective secretion of the colouring fluid, without any privation of nutrition. In this case, the hairs may live and retain their hold, as we observe in young individuals:—and *secondly*, to the canals, which convey the fluid into the hair, being obliterated, as in old age. The same cause, acting on the nutritious vessels of the bulb, produces, successively, privation of colour, death, and loss of those epidermoid productions.

According to other physiologists, the seat of colour is in the horny covering of the hair; and, in the largest hairs or spines of the porcupine, this seems to be the case, the pith being white, and the horny covering coloured. There is often an intimate relationship observed between the colour of the hair and that of the rete mucosum. A fair complexion is accompanied with light hair; a swarthy with dark;—and we see the connexion still more signally displayed in those animals that are spotted—the colour of the hair being variegated like that of the skin.

Hairs differ materially according to the part of the body on which they grow. In some parts they are short, as in the armpits; whilst on the head it is not easy to say what would be the precise limit to the growth, were they left entirely to nature. In the Malay, it is by no means uncommon to see them touch the ground.

The hair has various names assigned to it, according to the part on which it appears,—*beard*, *whiskers*, *mustachios*, *eyebrows*, *eyelashes*, &c. In many animals it is long and straight; in others crisped, when it is called *wool*. If stiff, it is termed a *bristle;* if inflexible, a *spine*. It is entirely insensible, and, excepting in the bulbous portion, is not liable to disease. Dr. Bostock affirms, that under certain circumstances hairs are subject to a species of inflammation, when vessels may be detected, at least in some of them, and they become acutely sensitive. Their sensibility under any known circumstances may be doubted. They appear to be anorganic, except at the root; and, like the cuticle, resist putrefaction for a length of time. The parts that do not receive vessels are nourished by transudation from those that do. Bichat and Gaultier were of the opinion of Dr. Bostock;—misled, apparently, by erroneous reports concerning plica polonica; but Baron Larrey[2] has satisfactorily shown that plica is confined to the bulbs: the hairs themselves continue devoid of sensibility.

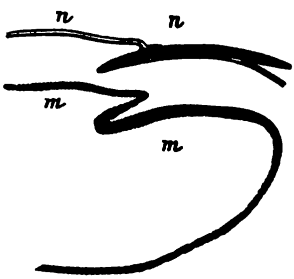
It is difficult to assign a plausible use for the hair. That of the head has already engaged attention; but the hair, which appears on certain parts at the age of puberty and not till then, and that on the chin and upper lip of the male sex only, set our ingenuity at defiance. In this respect, the hair is not unique. Many physiologists regard certain parts, which exist in one animal, apparently without function, but which answer useful purposes in another, to be *vestiges* indicating the harmony that reigns through nature's works. The generally useless nipple and mamma of one sex might be looked upon in this light; but

[1] Traité de Physiologie Médicale et Philosophique, tom. iii. p. 42, Paris, 1832.
[2] Mémoires de Chirurgie Militaire, t. iii. 108, Paris, 1812.

the tufts of hair on various parts cannot, in any way, be assimilated to the hairy coating that envelopes the bodies of animals; and is, in them, manifestly intended as a protection against cold.

There is another class of bodies connected with the skin, and analogous in nature to the last described,—the *nails*. These serve a useful purpose in touch, and consequently require notice here. In the system of De Blainville, they constitute a subdivision of the hairs, which he distinguishes into *simple* and *compound*,—*simple*, when each bulb is separated, and has a distinct hair;—*compound*, when several pileous bulbs are agglomerated, so that the different hairs, as they are formed, are cemented together to constitute a solid body of greater or less size,—*nail*, *scale*, *horn*, &c. In man, the nail alone exists; the chief and obvious use of which is to support the pulp of the finger, whilst it is exercising touch. Animals are provided with horns, beaks, hoofs, nails, spurs, scales, &c. All these, like the hair, grow from roots; and are considered to be analogous in their physical and vital properties. Meckel, and De Blainville, Bonn, Walther, Lavagna, and others, are of opinion, that the teeth are of the same class; and that they belong, originally, to the skin of the mouth.

Fig. 46.



Section of the Skin on the end of the Finger.

The cuticle and nail, *n*, detached from the cutis and matrix, *m*.

The nails, near their origin, are seen, under the microscope, to consist of primary cells, almost identical with those of the epidermis; these gradually dry into scales; and the growth of the nail appears to be effected by the constant generation of cells at its root and under surface; and as successive layers are pushed forward, each cell becomes larger, flatter, and drier, and more firmly fixed than those around it.[1] The chemical composition of the epidermis and the nails is similar to that of the hair: yet according to Mulder,[2] there are material differences in their properties;—the latter, being almost insoluble in strong acetic acid, in which the other two are readily soluble: hence—he infers—the composition of hair and of horn and whalebone must differ materially; and, that, accordingly, Scherer's conclusion, that they are all identical is incorrect. The following are the results of the analysis of each of these bodies.

	Epidermis.	Horn.	Whalebone.	Hair.
C.	50.28	51.03	51.86	50.65
H.	6.76	6.80	6.87	6.36
N.	17.21	16.24	15.70	17.14
O.	25.01	22.51	21.97	20.85
S.	0.74	3.42	3.60	5.00

For physiological purposes, the above description is sufficient. A few

[1] Henle, edit. cit., i. 289, Paris, 1843.
[2] The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, p. 527. Edinb. and London, 1849.

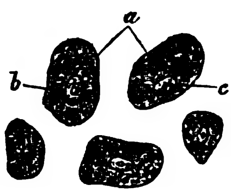
words will be necessary regarding the *mucous membranes*, which resemble the skin so much in their properties, as to be, with propriety, termed *dermoid*. If we trace the skin into the various outlets, we find, that a continuous, soft, velvety membrane—*epithelium*—exists through their whole extent; and, if the channel has two outlets, as in the alimentary canal, this membrane, at each outlet, commingles with the skin; and appears to differ but slightly from it. So much, indeed, do they seem to form part of the same organ, that physiologists have described the absorption, that takes place from the intestinal mucous membrane, as *external*. They cannot, however, in the higher order of animals, be considered completely identical; nor is the same membrane alike in its whole extent. They have all been referred to two great surfaces;—the *gastro-pulmonary*—comprising the membranes of the outer surface of the eye, ductus ad nasum, nose, mouth, and respiratory and digestive passages; and the *genito-urinary*—which line the whole of the genital and urinary apparatuses. In addition to these, a membrane of similar character lines the meatus auditorius externus, and the excretory ducts of the mammæ.

The analogy between the skin and mucous membranes is farther shown by the fact, that if we invert the polypus, the mucous membrane gradually assumes the characters of skin; and the same circumstance is observed in habitual descents of the rectum and uterus.

In the mucous membranes—especially at their extremities, which appear to be alone concerned in the sense of touch—the same superposition of strata is generally considered to exist as in the skin—viz., epidermis or epithelium, rete mucosum, corpus papillare, and cutis vera. They have, likewise, similar follicles, called *mucous;* but nothing

Fig. 47.

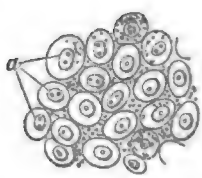
A



Separated Epithelium Cells from mucous membrane of mouth.

b. With nuclei. *c*. And nucleoli.

B



Pavement-Epithelium of the Mucous Membrane of the smaller bronchial tubes.

a. Nuclei with double nucleoli.

analogous to the hairs; unless we regard the teeth to be so, in correspondence with the views of Meckel, De Blainville, and others.

The attention of anatomists has been closely directed to the ultimate structure of the mucous system. In the mucous tissues two structures have been separately described, especially by Mr. Bowman,[1] who has thrown much light on the subject. These are the *basement membrane*—as he terms it—and *the epithelium*. The former is a simple, homogeneous expansion, transparent, colourless, and of extreme tenuity, situate

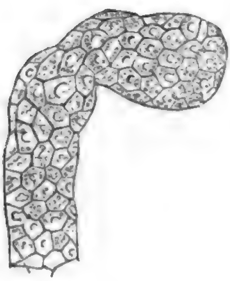
[1] Cyclopædia of Anat. and Physiology, pt. xxiii. p. 486, April, 1842.

on its parenchymal surface, and giving it shape and strength. This serves as a foundation on which the epithelium rests. It may frequently be demonstrated with very little trouble in the tubuli of the glands, especially of the kidney, which are but very slightly adherent, by their external surface, to the surrounding tissue.

M. Flourens[1] considers that every mucous membrane is composed of three laminæ or layers,—the derma, epidermis, and corpus mucosum situate between the derma and epidermis. The corpus mucosum of mucous membranes is continuous at all the outlets of the body, and is identical with the second epidermis; differing, therefore, from the corpus mucosum of the skin, a term which—as elsewhere remarked—he thinks ought to be abolished.

Histological examination exhibits the epithelium to consist of cells, which are termed *epithelial*, and have various shapes. The two chief are *tesselated* or *pavement epithelium*, and *cylinder* or *conical epithelium*. Epithelium is not, however, confined to mucous membranes, but, of late years, has been found to exist elsewhere; it is always in contact with fluids, and of a soft, pliant character. *Tesselated epithelium* covers the serous and synovial membranes, the lining membrane of the blood-vessels, and the mucous membranes, except where cylinder epithelium exists. It is spread over the mouth, pharynx and œsophagus, conjunctiva, vagina, and entrance of the female urethra. The cells composing it are usually polygonal; and are well seen in the marginal figure. *Cylinder epithelium* is found in the intestinal canal, beyond the cardiac orifice, in the larger ducts of the salivary glands, in the ductus communis choledochus, prostate, Cowper's glands, vesiculæ seminales, vas deferens, tubuli uriniferi, and urethra of the male; and lines the urinary passages of the female from the orifice of the urethra to the beginning of the tubuli uriniferi of the kidneys. In all these situations, it is continuous with tesselated

Fig. 48.



Tesselated Epithelium.

Extremity of one of the tubuli uriniferi, from the kidney of an adult; showing its tesselated epithelium.—Magnified 250 diameters. (Wagner.)

Fig. 49.

Scales of Tesselated Epithelium. (After Henle.)

A. Section of epithelium of conjunctiva with some scales loosened. B. Scales from surface of cheek. C. The more deeply seated scales from the human conjunctiva.

epithelium, which lines the more delicate ducts of the various glands. The cells have the form of long cylinders or truncated cones, arranged side by side, the apices attached to the mucous membrane or to flat

[1] Op. cit., p. 80.

Fig. 50.

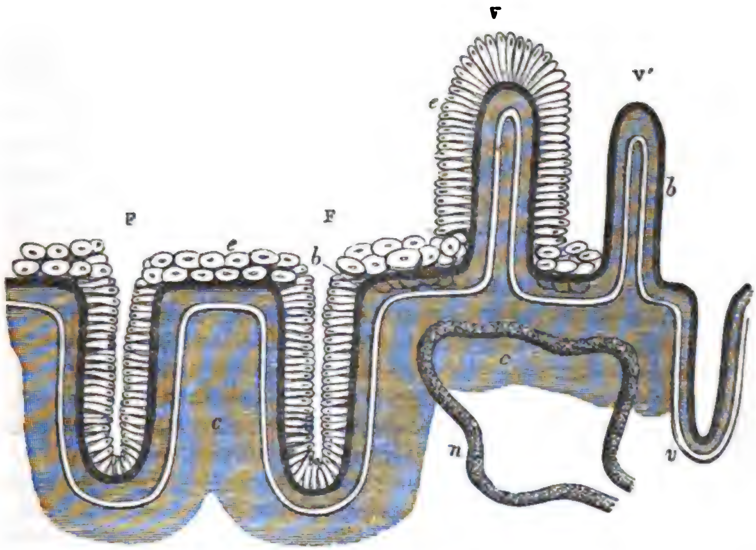
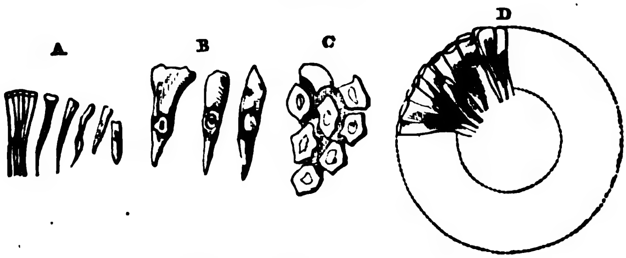


Diagram of the Structure of an Involuted Mucous Membrane, showing the continuation of its elements in the follicles and villi.

F, F. Two follicles. *b*. Basement membrane. *c*. Submucous tissue. *e*. Epithelium. *v*. Vascular layer. *n*. Nerve. V. Villus, covered with epithelium. V'. Villus, whose epithelium has been shed.

epithelial cells lying upon it; the base being free. Each cell, nearly midway between the base and apex, encloses a flat nucleus with nucleoli.

Fig. 51.



Cylinders of Intestinal Epithelium. (After Henle.)

A. From the cardiac region of the human stomach. B. From jejunum. C. Cylinders seen when looking on their free extremities. D. Ditto, as seen in a transverse section of a villus.

Epithelium is sometimes furnished with *cilia*, or is said to be *ciliated*. The nature and uses of these cilia, as well as the different varieties of mucous membrane, will be described hereafter.

2. PHYSIOLOGY OF TACT AND TOUCH.

In describing the physiology of the sense of touch, it will be convenient to revert to the distinction already made between the sense when passively and actively exerted; or between *tact*, and *touch*. The mode,

however, in which the impression is made is in each case alike, and equally simple. It is merely necessary, that the substance, which causes it, should be brought in contact with what may be termed the physical part of the organ—the cuticle; the nervous part is seated in the corpus papillare, for if the nerves proceeding to this layer of the skin be cut, the sense is destroyed. In the exercise of touch, each of the layers seems to have its appropriate office: the corium, the innermost layer, the base on which the others rest, offers the necessary resistance, when bodies are applied to the surface; the rete mucosum is unconcerned in the function: the erectile tissue, on which the papillæ are grouped, probably aids them in their appreciation of bodies; and the epidermis modifies the tactile impression which might become too intense, or be painful, did this anorganic envelope not exist. The degree of perfection of the sense is greatly influenced by the state of the cuticle. Where thin—as upon the lips, glans penis, clitoris, &c.—the sense is very acute; where thick and hard, it is obtuse; and where removed—as by blistering—the contact of bodies gives pain, but does not occasion the appropriate impression of touch.

Professors Weber[1] and Valentin[2] have shown that the tactile power of the skin is not proportionate to its sensibility. The mammæ, for example, are easily tickled, and susceptible of great pain when irritated; yet they are moderately endowed with the sense of touch. The different parts of the skin, too, vary in their tactile power. The left hand, in most persons, is more sensible to temperature than the right, probably owing to the epidermis being thinner from less use. Weber made various experiments for the purpose of determining the relative sensibility of different portions of the skin, by touching the surface with the legs of a pair of compasses, the points of which were inserted into pieces of cork. The person's eyes being closed at the time, the legs were brought together so as to be separated by different distances. The following are some of the results of his experiments.

	Lines.		Lines.
Point of middle finger	[illegible]	Mucous membrane of gums	9
Point of tongue	$\frac{1}{2}$	Lower part of forehead	10
Palmar surface of third finger	1	Lower part of occiput	12
Red surface of lips	2	Back of hand	14
Palmar surface of middle finger	2	Neck, under lower jaw	15
Dorsal surface of third finger	3	Vertex	15
Tip of the nose	3	Skin over patella	16
Dorsum and edge of tongue	4	Skin over sacrum	18
Part of lips covered by skin	4	——— acromion	18
Palm of hand	5	Dorsum of foot	18
Skin of cheek	5	Skin over sternum	20
Extremity of great toe	5	Skin beneath occiput	24
Hard palate	6	Skin over spine, in back	30
Dorsal surface of fore finger	7	Middle of the arm	30
Dorsum of hand	8	——— thigh	30

Weber found, that the distance between the legs of the compasses

[1] See art. Tastsinn und das Gemeingefühl, in Wagner's Handwörterbuch der Physiologie, 22ste Lieferung, s. 539. Braunschweig, 1849. His earlier experiments are detailed and confirmed by Dr. Allen Thomson, in Edinb. Med. and Surg. Journal, for July, 1833.

[2] Lehrbuch der Physiologie des Menschen, ii. 565. Braunschweig, 1844; and Grundriss der Physiologie, s. 331. Braunschweig, 1846.

seemed to be greater, although it was really less, when they were placed upon more sensitive parts.

It has been supposed, that some of the recorded instances of great resistance to heat have been caused by unusual thickness, and compactness of cuticle, together with a certain degree of insensibility of the skin. The latter may be an important element in the explanation; but some of the feats, executed by persons of the character alluded to, could hardly have been influenced by the former, as the resistance seemed almost equally great in the delicately organized mucous membranes. A Madame Girandelli,—who was exhibited in Great Britain many years ago,—was in the habit of drawing a box with a dozen lighted candles along her arm, putting her naked foot upon melted lead, and of dropping melted sealing-wax upon her tongue, and impressing it with a seal, without appearing to experience uneasiness; and several years ago (1832), a man of the name of Chabert excited in this country the surprise which followed his exhibitions in London a year or two previously, and gave him the appellation of the "Fire King." In addition to the experiments performed by Madame Girandelli, Chabert swallowed forty grains of phosphorus; washed his fingers in melted lead; and drank boiling Florence oil with perfect impunity. For the phosphorus he professed to take an antidote, and doubtless did so. It is probable, also, that agents were used by him to deaden the painful impressions ordinarily produced by hot bodies applied to the surface. A solution of borax or alum spread upon the skin is said to exert a powerful effect of the kind; but, in addition to the use of such agents, there must be a degree of insensibility of the corpus papillare; otherwise it is difficult to understand why those hot substances did not painfully inflame the surface. We see, daily, striking differences in individuals in the degree of sensibility of the mucous membrane of the mouth and gullet, and are frequently surprised at the facility with which certain persons swallow fluids of a temperature that would excite the most painful sensations in others. In this, habit has unquestionably much to do.

In the mucous membranes, tact is effected in the same way as in the skin. The layers, of which it is constituted, participate in like manner; but the sense is more exercised at the extremities of the membrane than internally. The food, received into the mouth, is felt there; but after it has passed into the gullet it excites hardly any tactile impression; and it is not until it has reached the lower part of the membrane, in the shape of excrement, that its presence is again indicated by this sense.

Pathologically, we have some striking instances of this difference in different parts of the mucous membrane. If an irritation exists within the intestinal canal, the only indication we may have of it is itching of the nose, or at one extremity of the membrane. In like manner, a calculus in the bladder is indicated by itching of the glans penis; and a similar exemplification is offered during the passage of a gall-stone through the ductus communis choledochus. On its first entrance, the pain experienced is of the most violent character; this, after a time subsides,—as soon, indeed, as the calculus has got fairly into the canal.

One of the great purposes of the sense of tact is to enable us to judge of the temperature of bodies. This office it executes alone. No other sense participates in it. It requires no previous exercise; is felt equally by the infant and the adult, and requires only the proper development of its organs. The relative temperature of bodies is accurately designated by the instrument called the *thermometer;* but very inaccurately by our own sensations; and the reason of this inaccuracy is sufficiently intelligible. In both cases, the effect is produced by the disengagement of a subtile fluid, called *caloric* or the matter of heat, which pervades all bodies, and is contained in them to a greater or less extent. This caloric is constantly passing and repassing between bodies, either by radiation or by conduction, until there is an equilibrium of caloric and all have the same temperature as indicated by the thermometer. Hence, objects in the same apartment will exhibit, *cæteris paribus*, a like temperature by this test. From this law, however, the animal body must be excepted. The power which it possesses of generating its own heat, and of counteracting the external influences of temperature, preserves it constantly at the same point.

Although, however, all objects may exhibit the same temperature, in the same apartment, when the thermometer is applied to them; the sensations communicated by them may be very different. Hence the difficulty, which the uninstructed have in believing, that they are actually of identical temperature;—that a hearth-stone, for instance, is of the same degree of heat as the carpet in the same chamber. The cause of the different sensations experienced in the two cases is, that the hearth-stone is a much better *conductor* of the matter of heat than the carpet. The consequence is, that caloric is more rapidly abstracted by it from the part of the body which comes in contact with it, and the stone appears to be the colder of the two. For the same reason, when these two substances are raised in temperature above that of the human body, the hearth-stone will appear the hotter of the two; because, it conducts caloric and communicates it more rapidly to the body than the carpet.

When the temperature of the surrounding air is higher than 98°, we receive caloric from the atmosphere, and experience the sensation of heat. The human body is capable of being penetrated by the caloric of substances exterior to it, precisely like those substances themselves; but, within certain limits, it possesses the faculty of consuming the heat, and retaining the same temperature. When the temperature of the atmosphere is only as high as our own—an elevation which it not unfrequently attains in many parts of the United States—we still experience the sensation of unusual warmth; yet no caloric is communicated to us. The cause of this feeling is, that we are accustomed to live in a medium of a less elevated temperature, and consequently to give off caloric habitually to the atmosphere.

Lastly, in an atmosphere of a temperature much lower than that of the body, heat is incessantly abstracted from us; and, if rapidly, we have the sensation of cold. From registers, kept by the illustrious founder of the University of Virginia, Mr. Jefferson, at his residence at Monticello,[1] lat. 37° 58′, long. 78° 40′, it appears that the mean

[1] Virginia Literary Museum, p. 36, Charlottesville, 1830.

temperature of that part of Virginia, is about 55½° or 56°; and that the thermometer varies from 5½° in the coldest month, to 94° in the warmest. Now, the temperature of the human body being 98°, it follows, that heat must be incessantly parting from us, and that we ought, therefore, to experience constantly a sensation of cold; and this we should unquestionably do, were we not protected by clothing, and aided by artificial temperature during the colder seasons. Yet, accustomed as the body is to give off caloric, there is a temperature, in which, clothed as we are, we do not feel cold, although we may be disengaging heat to some extent. This temperature may perhaps be fixed somewhere between 70° and 80° in the climate of the middle portions of the United States. So much, however, are our sensations in this respect dependent upon the temperature which has previously existed, that the *comfortable point* varies at different seasons. If the thermometer, for instance, has ranged as high as 98°, and has maintained this elevation for a few days, a depression of 15° or 20° will be accompanied by feelings of discomfort; whilst a sudden elevation from 30° to 75° may occasion an oppressive feeling of heat. In northern Siberia, M. von Wrangel[1] found, that only a few degrees of frost was currently denominated "warm weather;" and that after having been accustomed to the winter temperature of that climate, it seemed to him, that 10° of cold, 22° below the freezing point of Fahrenheit, was a mild temperature. During the voyages, made by Captain Parry and others to discover a northwest passage, it was found, that after having lived for some days in a temperature of 15° or 20° below 0, it felt comfortable when the thermometer rose to zero.

These are the great sources of the deceptive nature of our sensations as to warmth and cold which enable us to judge merely of the comparative conditions of the present and the past; and hence it is, that a deep cellar appears warm in winter and cold in summer. At a certain distance below the surface, the temperature of the earth indicates the medium heat of the climate; yet, although this may be stationary, our sensations on descending to it in winter and summer would be by no means the same. If two men were to meet on the middle of the South American Andes,—the one having descended, and the other ascended,—their sensations would be very different. The one, who had descended, coming from a colder to a warmer atmosphere, would experience warmth; whilst the other, who had ascended, would feel correspondently cool. An experiment, often performed in the chemical lecture-room, exhibits the same physiological fact. If, after having held one hand in iced, and the other in warm water, we plunge both into water of a medium heat, it will seem warm to the one hand, and cold to the other.

But our sensations are not guided solely by bodies surrounding us. They are often greatly dependent, especially in disease, on the state of the animal economy itself. If the power, which the system possesses of forming heat, be morbidly depressed—or if, in consequence of old age, or of previous sickness, calorification does not go on regularly and energetically, a temperature of the air, which to the vigorous is agree-

[1] Reise des kaiserlich Russischen Flotten Lieutenants F. v. Wrangel, langs der Nordküste von Siberien, u. s. w. Berlin, 1839, translated in Harper's Family Library.

able, may produce an unpleasant impression of cold. Under opposite circumstances, a feeling of heat exists.

In regard to the mode in which the temperature of bodies is appreciated, there are peculiarities, which would favour the idea of the sense of heat being distinct from that of tact or touch. Professor Weber, for example, found that the left hand is more sensitive than the right, although the sense of touch is more acute in the latter; and that if the two hands, at the time of like temperature, be plunged into separate basins of water, the one in which the left hand is, will appear to be the warmer, even although its temperature may be somewhat lower than that of the other. It would seem, too, from Weber's experiments, that in regard to sensations of heat and cold, a weaker impression made upon a large surface appears more powerful than a stronger made upon a small surface; and, accordingly, to judge of nice shades of difference in the temperature of a fluid, the whole hand will enable a variation to be detected, that would be inappreciable to the finger. A difference of one-third of a degree it is affirmed, may be easily detected, when the same hand is placed successively in two vessels of water, or any other fluid.[1]

These and other phenomena of an analogous kind have led to the suggestion, that every nerve of sensation is composed of several nerves, each of which may have its special function; and that the nerves of touch comprise some which appreciate temperature, others, which perceive the resistance of bodies, and others which effect touch properly so called. In proof of this a recent writer urges that either of these faculties may be lost, without the other being so. Thus, when the arm has been "asleep," and sensibility is returning to it, the hand first perceives temperature, then the resistance of bodies, and it is not until some time afterwards that the faculty of touch, properly so called, is exercised. In the lower extremities the contrary takes place; the sense of touch first returns; then a sensation of pricking is experienced, followed by the perception of temperature, and the power of appreciating resistance returns last. It may be added, that many cases are recorded, in which the sense of temperature has been lost, whilst the ordinary sense of tact remained; and, as remarked by Dr. Carpenter,[2] it is an additional evidence in favour of the distinctness of nervous fibres to convey the impressions of temperature, that these are frequently affected,—a person being sensible of heat or of chilliness in some part of the body,—without any real alteration of its temperature, whilst there is no corresponding affection of the tactile sensations.

By tact we are likewise capable of forming a judgment of many of the qualities of bodies,—such as their size, consistence, weight, distance, and motion. This faculty, however, is not possessed exclusively by the sense in question. We can judge of the size of bodies by the sight; of distance, to a certain extent, by the ear, &c. To appreciate these characters, it is necessary, that the sense should be used actively; that we should call into exercise the admirable instrument with which we are

[1] E. H. Weber, Art. Tastsinn und das Gemeingefühl in Wagner's Handwörterbuch der Physiologie, 22ste Lieferung, s. 549. Braunschweig, 1849.

[2] Principles of Physiology, 2d Amer. edit., p. 229. Philad., 1845.

provided for that purpose; and in many of them we are greatly instructed by the muscular sense.

In treating of the external senses generally, it was remarked, that we are capable of judging, by their aid, of impressions made on us by portions of our own body. By the sense of touch we can derive information regarding its temperature, shape, consistence, &c. An opinion has, indeed, been advanced, that this sense is best adapted for proving our own existence, as every time that two portions of the body come in contact, two impressions are conveyed to the brain, whilst if we touch an extraneous body, there is but one.

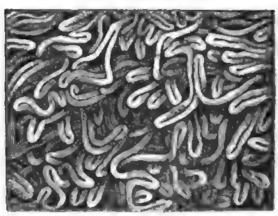
The tact of mucous membranes is extremely delicate. The great sensibility of the lips, tongue, tunica conjunctiva, Schneiderian membrane, lining membrane of the trachea and urethra, is familiar to all. Excessive pain is produced in them by the contact of extraneous bodies; yet, in many cases, they signally exemplify the effect of habit in blunting sensation. The first introduction of a bougie into the urethra generally produces intense irritation; but after a few repetitions the sensation may become scarcely disagreeable.

To appreciate accurately the shape and size of objects, it is necessary, that they should be embraced by a part of the body, which can examine their surfaces, and be applied to them in every direction. In man, the organ well fitted for this purpose is the hand. This is situate at the free extremity of a long and flexible member, which admits of its being moved in every direction, and renders it not only well adapted for the organ of touch, but for that of prehension. Man alone possesses a true hand; for although other animals have organs of prehension very similar to his, they are much less complete. Aristotle and Galen termed it the *instrument of instruments*, and its construction was considered worthy of forming the subject of one of the "*Bridgewater Treatises*" "On the Power, Wisdom, and Goodness of God, as manifested in the Creation,"—a task assigned to Sir Charles Bell.

The chief superiority of the hand consists in the size and strength of the thumb, which stands out from the fingers, and can be brought in opposition to them, so as to enable us to grasp bodies, and to execute various mechanical processes under the guidance of the intellect. So important was the thumb esteemed by Albinus,[1] that he called it a lesser hand to assist the larger—"*manus parva majori adjutrix.*"

In addition to the advantages referred to, the hand is furnished with a highly sensible integument. The papillæ are largely developed, especially at the extremities of the fingers, where they are ranged in concentric circles, and rest upon a spongy tissue, by many considered to be erectile, and serving as a cushion, and are well supplied with capillary vessels. (See Figs. 33 and 52.) At the posterior extremity of the fingers, are the nails, which support the pulps of the fingers behind; and render the contact with external bodies more immediate. This happy

Fig. 52.



Capillary Net-work at margin of lips.

[1] De Sceleto, p. 465.

organization of the soft parts of the hand alone concerns the sense of touch directly. The other advantages, which it possesses, relate to the power of applying it under the guidance of volition.

Of the mode in which touch is effected it is not necessary to treat. Being nothing more than tact, exerted by an appropriate instrument, the physiology of the two must be identical.

Metaphysicians have differed widely regarding the services that ought to be attributed to the touch. Some have greatly exaggerated them, considering it *the sense par excellence*, the *first of the senses*. It is an ancient notion to ascribe the superiority of man over animals and his pre-eminence in the universe—his intelligence, in short—to the hand. Anaxagoras asserted, and Helvetius[1] revived the idea, "that man is the wisest of animals because he possesses hands." The notion has been embraced, and expanded by Condillac,[2] Buffon,[3] and many modern physiologists and metaphysicians. Buffon assigned so much importance to the touch, that he believed the cause why one person has more intellect than another is his having made a more prompt and repeated use of his hands from early infancy. Hence, he recommended, that infants should use them freely from the moment of birth. Other metaphysicians have considered the hand the source of mechanical capabilities; but the same answer applies to all these views. It can only be regarded as an instrument by which information of particular kinds is conveyed to the brain; and by which other functions are executed, under the direction of the will. The idiot often has the sense more delicate than the man of genius or than the best mechanician, whilst the most ingenious artists have by no means the most delicate touch. We have, indeed, some striking cases to show, that the hand is not entitled to this extravagant commendation. Not many years ago, a Miss Biffin was exhibited in London, who was totally devoid of upper and lower extremities; yet she was unusually intelligent and ingenious. It was surprising to observe the facility with which she hem-stitched; turning the needle with the greatest rapidity in her mouth, and inserting it by means of the teeth. She painted miniatures faithfully, and beautifully;—holding the pencil between her head and neck. All her motions were, in fact, confined to the tongue and lips, and to the muscles of the neck. M. Magendie[4] alludes to a similar case. He says, that there was, in Paris, at the time he wrote, a young artist, who had no signs of arm, forearm, or hand, and whose feet had one toe less than usual, —the second; yet his intelligence was in no respect inferior to that of boys of his age; and he even gave indications of distinguished ability. He sketched and painted with his feet. Not many years ago, a Miss Honeywell, born without arms, travelled about this country. She had acquired so much dexterity in the use of the scissors, as to be able, by holding them in her mouth, to cut likenesses, watch-papers, flowers, &c. She also wrote, drew, and executed all kinds of needlework with the utmost ease and despatch. How fatal are such authentic examples to the views of Helvetius and others!

[1] De l'Homme, &c., tom. i.
[2] Traité des Sensations, P. i.
[3] Histoire Naturelle, tom. vi.
[4] Précis Elémentaire, 2de édit., i. 154, Paris, 1825.

But, it has been said, that touch is the least subject to error of all the senses: it is the *regulating*—the *geometrical* sense. In part only is this accurate. It certainly possesses the advantage of allowing the organ of sense to be brought into immediate contact with the body that excites the impression; whilst, in the case of olfaction, the organ receives the impression of an emanation from the body; and, in vision and audition, only the vibration of an intervening medium. Yet some of the errors into which touch falls are as grievous as those that happen to the other senses. How inaccurate is its appreciation of the temperature of bodies! We have attempted to show, that it affords merely relative knowledge,—the same substance appearing hot or cold to us, according to the temperature of the substance previously touched. Nay, infallibility so little exists, that we have the same sensation communicated by a body that rapidly abstracts caloric from us, as by one that rapidly supplies it. By touching frozen mercury, which requires a temperature of —40° of Fahrenheit to be congealed, we experience the sensation of a burn. Again, if we cross the fingers and touch a rounded body—a marble, for instance—with two of the pulps at the same time; instead of experiencing the sensation of one body, we feel as if there were two,—an illusion produced by the lateral portions of fingers being brought in apposition, which are naturally in a different situation, and at a distance from each other; and, as these two parts habitually receive distinct impressions when separated, they continue to do so when applied to opposite sides of the rounded body.

It has been asserted, that the touch is the great corrector of the errors into which the other senses fall. But let us inquire, whether, in this respect, it possesses any decided superiority over them. For this purpose, the distinction of the sensory functions into *immediate* and *mediate* has been adopted. Each sense has its immediate function, which it possesses exclusively; and for which, no other can be substituted. The touch instructs us regarding resistance; the taste appreciates savours; the smell, odours; audition, sound; and vision, colours. These are the *immediate* functions of the senses, each of which can be accomplished by its own organs, but by no other. As concerns the immediate functions of the senses, therefore, the touch can afford no correction. Its predominance, as regards the *mediate* functions of the senses, is likewise exaggerated. The *mediate* functions are those that furnish impressions to the mind; and by aid of which it acquires its notions of bodies. The essential difference between these two sets of functions is, that the mediate can be effected by several senses at once, and may be regarded as belonging to the cerebrum. Vision, olfaction, and audition participate in enabling us to judge of distances, as well as touch; the sight instructs us regarding shape, &c. It has been affirmed by metaphysicians, that touch is necessary to several of the senses to give them their full power, and that we could form no notion of the size, shape, and distance of bodies, unless instructed by this sense. The remarks already made have proved the inaccuracy of this opinion. The farther examination of it will be resumed under Vision. The senses are, in truth, of mutual assistance. If the touch falls into error, as in the

case of inaccurate appreciation of temperature, the sight, aided by appropriate instruments, dispels it. If the crossed fingers convey to the brain the sensation of two rounded bodies, when one only exists, the sight apprises us of the error; and if the sight and touch united impress us with a belief in the identity of two liquids, the smell or the taste will often detect the erroneous inference.

But, it has been said by some, touch is the only sense that gives us any notion of the existence of bodies. M. Destutt-Tracy[1] has satisfactorily opposed this, by showing that such notion is a work of the mind, in acquiring which the touch does not assist more immediately than any other sense. "The tactile sensations," he observes, "have not of themselves any prerogative essential to their nature, which distinguishes them from others. If a body affects the nerves beneath the skin of my hand, or if it produces certain vibrations in those distributed on the membranes of my palate, nose, eye, or ear, it is a pure impression which I receive; a simple affection which I experience; and there seems to be no reason for believing that one is more instinctive than another; that one is more adapted than another for enabling me to judge that it proceeds from a body exterior to me. Why should the simple sensation of a puncture, burn, titillation, or pressure, give me more knowledge of the cause, than that of a colour, sound, or internal pain? There is no reason for believing it." There are, indeed, numerous classes of bodies, regarding whose existence the touch affords us no information, but which are detected by the other senses.

On the whole, then, we must conclude, that the senses mutually aid each other in the execution of certain of their functions; that each has its province, which cannot be invaded by others; and that too much preponderance has been ascribed to the touch by metaphysicians and physiologists. Ministering, however, as it does, so largely to the mind, it has been properly ranked with vision and audition as an intellectual sense.[2]

By education, the sense of touch is capable of acquiring extraordinary acuteness. To this circumstance must be ascribed the surprising feats we occasionally meet with in the blind. For all their reading and writing they are, indeed, indebted to this sense. Saunderson—who lost his eyesight in the second year of his life, and was Professor of Mathematics at Cambridge, England—could discern false from genuine medals; and had a most extensive acquaintance with numismatics.[3] As an instance of the correct notions, which may be conveyed to the mind of the forms and surfaces of a great variety of objects, and of the sufficiency of these notions for accurate comparison, Dr. Carpenter[4] mentions the case of a blind friend, who has acquired a very complete knowledge of conchology, both recent and fossil; and who is not only able to recognize every one of the numerous specimens in his own cabinet, but to mention the nearest alliances of a shell previously unknown

[1] Elémens d'Idéologie, 1ère Partie p. 114, 2de édit. Paris, 1804.
[2] Gall, Sur les Fonctions du Cerveau, i. 99, Paris, 1825.
[3] Abercrombie's Inquiries concerning the Intellectual Powers; Amer. edit., p. 55, New York, 1832.
[4] Principles of Human Physiology, 4th American edit., § 525, Philad., 1850.

to him, when he has thoroughly examined it by the touch. Baczko, referred to by Rudolphi,[1] who describes his own case, could discriminate between samples of woollen cloth of equal quality but of different colours. The black appeared to him among the roughest and hardest: to this succeeded dark blue and dark brown, which he could not, however, distinguish from each other. The colours of cotton and silk stuffs he was unable to discriminate; and he properly enough doubts the case of a Count Lynar, blind, who, it was said, was capable of judging of the colour of a horse by the feel. The only means the blind can possess of discriminating colours must be through the physical differences of surface, which render it capable of reflecting one ray or combination of rays, whilst it absorbs the rest; and if these differences were insufficient to enable Baczko to detect the differences between cotton and silk fabrics, it is not probable, that the sleek surface of the horse would admit of such discrimination.

In animals the organ of touch varies. The monkey's resembles that of man. In other quadrupeds, it is seated in the lips, snout, or proboscis. In molluscous animals, the tentacula; and in insects, the antennæ or feelers, are organs of touch, possessing, in some, very great sensibility. Bats appear to have this to an unusual degree. Spallanzani observed them, even after their eyes had been destroyed and the ears and nostrils closed, flying through intricate passages, without striking the walls, and dexterously avoiding cords and lines placed in the way. The membrane of the wings is, in the opinion of Cuvier and many others,[2] the organ that receives an impression produced by a change in the resistance of the air. M. Jurine concludes, that neither hearing nor smell is the channel through which they obtain perception of the presence and situation of surrounding bodies. He ascribes this extraordinary faculty to the great sensibility of the skin of the upper jaw, mouth, and external ear, which are furnished with large nerves; whilst Sir Anthony Carlisle attributes it to the extreme delicacy of hearing possessed by the animal;[3] a view which is confirmed by experiments instituted by the author's friend, Professor J. K. Mitchell, of Philadelphia. Certain experiments by Mr. Broughton,[4] sanction the idea that this may be, in part, dependent upon their whiskers. These, which are found on the upper lip of feline and other animals, are plentifully supplied with nerves, which seem to proceed from the second branch of the fifth pair, and are lost in the substance of the hairs. In an experiment, made by Mr. Broughton on a kitten, he found that whilst the whiskers were entire, it was capable of threading its way, blindfold, from a labyrinth in which it was designedly placed; but it was totally unable to do so when the whiskers were cut off. It struck its head repeatedly against the sides; ran against all the corners; and tumbled over steps placed in the way, instead of avoiding them, as it did prior to the removal of the whiskers.

From facts like these Mr. Broughton drew the conclusion, that cer-

[1] Grundriss der Physiologie, 2er Band, s. 85, Berlin, 1823.
[2] Carpenter, Human Physiology, p. 253, Lond., 1842.
[3] See Roget's Animal and Vegetable Physiology, ii. 399, Amer. edit., Philad., 1836.
[4] London Medical and Physical Journal, for 1823.

tain animals are supplied with whiskers for the purpose of enabling them to steer clear of opposing bodies in the dark.

SENSE OE TASTE OR GUSTATION.

The sense of taste teaches us the quality of bodies called *sapidity*. It is more nearly allied to touch in its mechanism than any other of the senses, as it requires the immediate contact of the body with the organ of taste, and the organ is, at the same time, capable of receiving tactile impressions distinct from those of taste. Of this we have a striking example, if we touch various portions of the tongue with the point of a needle. We find two distinct perceptions occasioned. In some parts the sensation of a pointed body without savour; and in others, a metallic taste is experienced. Pathological cases, too, exhibit, that the sense of taste may be lost, whilst general sensibility remains,—and conversely. The organ of gustation is not, therefore, restricted to that sense, but participates in touch. Yet so distinct are those functions, that touch can, in no wise, supply the place of its fellow sense, in detecting the sapidity of bodies. This last is the *immediate* instruction afforded by gustation.

1. ANATOMY OF THE ORGANS OF TASTE.

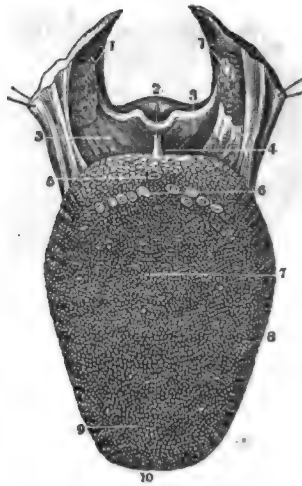
The chief organ of taste is the tongue, or rather the mucous membrane covering the upper surface, and sides of that organ. The lips, inner surface of the cheeks, palate, and fauces, participate in the function, especially when particular savours are concerned. M. Magendie[1] includes the œsophagus and stomach; but we know not on what grounds: his subsequent remarks, indeed, controvert the idea. The lingual branch of the fifth pair is, according to him, incontestably the nerve of taste; and, as this nerve is distributed to the mouth, we can understand, why gustation should be effected there; but not how it can be accomplished in the œsophagus and stomach. The tongue consists almost entirely of muscles, which give it great mobility, and enable it to fulfil the various functions assigned to it; for it is not only an organ of taste, but of mastication, deglutition, and articulation. The muscles being under the influence of volition, enable the sense to be executed passively or actively.

As regards gustation, the mucous membrane is the portion immediately concerned. This is formed, like the mucous membranes in general, of the different layers already described. The corpus papillare requires farther notice. If the surface of the tongue be examined, it will be found to consist of myriads of fine papillæ or villi, that give the organ a velvety appearance. These papillæ are, doubtless, like those of the skin, formed of the final ramifications of nerves, and of the radicles of exhalant and absorbent vessels, united by means of a spongy erectile tissue. Great confusion exists among anatomists in their descriptions of the papillæ of the tongue. Those certainly concerned in the sense of taste may, however, be included in two divisions:—1st, the *conical* or *pyramidal*,—the finest sort by some called *filiform;* and 2dly,

[1] Précis de Physiol., i. 139.

the *fungiform*. The former are broader at the base than at the top; and are seen over the whole surface of the tongue, from the tip to the root. The latter, which are larger at the top than the base, and resemble the mushroom, —whence their name,—are spread about, here and there, on the surface of the organ. These must be distinguished from a third set, the *papillæ capitatæ* or *circumvallatæ*, which are situate near the base of the tongue in two V shaped lines at the base of the organ. They are circular elevations from $\frac{1}{20}$th to $\frac{1}{12}$th of an inch wide, each with a central depression, and surrounded by a circular fissure, at the outside of which, again, is a slightly elevated ring; the central elevation and the ring being formed of close set simple papillæ. The epithelium of the tongue is of the tesselated variety, like that of the epidermis. Over the fungiform papillæ, it forms a thinner layer than elsewhere; so that they stand out more prominently than the rest. That which covers the conical papillæ, according to Messrs. Todd and Bowman,[1] has a singular arrangement; being extremely dense and thick, and projecting from their sides and tops in the form of long, stiff, hair-like processes; many of which bear a strong resemblance in structure to hairs; and some actually contain hair tubes.

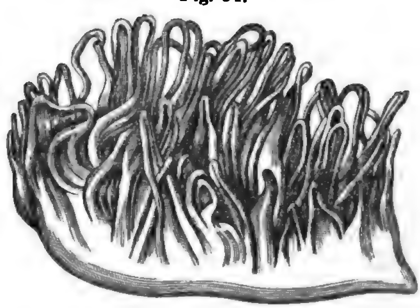
Fig. 53.



Front View of the Upper Surface of the Tongue, as well as of the Palatine Arch.

1, 1. Posterior lateral half arches, with the palato-pharyngei muscles and tonsils. 2. Epiglottic cartilage, seen from before. 3, 3. Ligament and mucous membrane, extending from the root of the tongue to the base of the epiglottic cartilage. 4. One of the pouches on the side of the posterior frænum, in which food sometimes lodges. 5. Foramen cæcum. 6. Papillæ conicæ, seu maximæ. 7. The white point at the end of the line, and all like it, are the papillæ fungiformes. 8. Side of the tongue, and rugæ transversæ of Albinus. 9. Papillæ filiformes. 10. Point of the tongue.

Fig. 54.



View of a Papilla of the smallest class, magnified 25 diameters.

The loops of blood-vessels are here shown, each loop containing usually only one vessel.

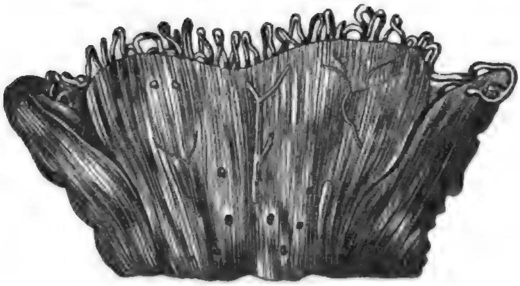
All the nerves that pass to the parts whose office it is to appreciate savours, must be considered to belong to the gustatory apparatus. These are the inferior maxillary; several branches of the superior, filaments from the spheno-palatine and naso-palatine ganglions; the lingual branch of the fifth pair, com-

[1] The Physiological Anat. and Physiology of Man, i. 439, Lond., 1848, or Amer. edit., p. 382.

monly called the *gustatory* nerve; the whole of the ninth pair or hypoglossal; and the glosso-pharyngeal. To which of these must be assigned the function of gustation, we shall inquire presently.

Like the skin and mucous membranes in general, that of the tongue and mouth contains, in its substance, numerous mucous follicles, which secrete a fluid that lubricates the organ, and keeps it in a condition adapted for the accomplishment of its functions. Some of these are placed very conspicuously in the mucous membrane of the tongue. They are the *papillæ capitatæ* of some anatomists—erroneously named, as they are not formed like papillæ, and execute a very different office. They are mucous follicles, and ought to be so called. The fluids, exhaled from the mucous membrane of the mouth, and the secretion of the different salivary glands, likewise aid in gustation; but they are more concerned in mastication and insalivation, and will require notice under another head.

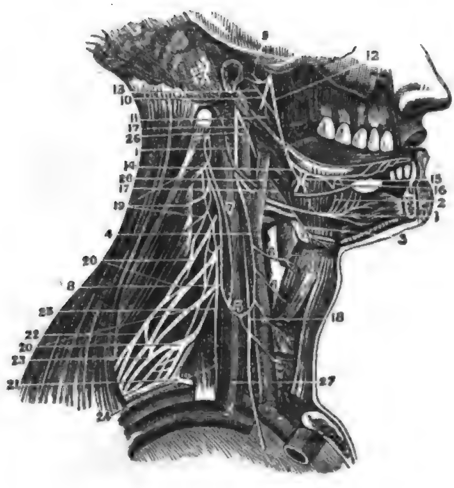
Fig. 55.



Vertical Section of one of the Gustatory Papillæ of the largest class, showing its conical form, its sides, and the fissure between the different Papillæ.

The length of some of the divided blood-vessels, a tranvserse section of others, and the vessels which rise up from the surface like loops or meshes, are also shown.

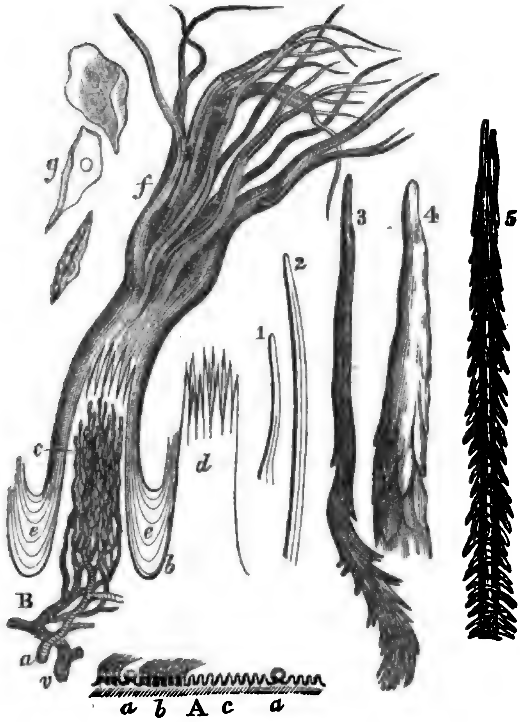
Fig. 56.



The Hypoglossal; Lingual branch of fifth pair; Glosso-Pharyngeal and deep-seated Nerves of the Neck.

1. The hypoglossal nerve. 2. Branches communicating with the gustatory nerve. 3. A branch to the origin of the hyoid muscles. 4. The descendens noni nerve. 5. The loop formed with the branch from the cervical nerves. 6. Muscular branches to the depressor muscles of the larynx. 7. A filament from the second cervical nerve, and 8, a filament from the third cervical, uniting to form the communicating branch with the loop from the descendens noni. 9. The auricular nerve. 10. The inferior dental nerve. 11. Its mylo-hyoidean branch. 12. The gustatory nerve. 13. The chorda-tympani passing to the gustatory nerve. 14. The chorda-tympani leaving the gustatory nerve to join the sub-maxillary ganglion. 15. The sub-maxillary ganglion. 16. Filaments of communication with the lingual nerve. 17. The glosso-pharyngeal nerve. 18. The pneumogastric or par vagum nerve. 19. The three upper cervical nerves. 20. The four inferior cervical nerves. 21. The first dorsal nerve. 22, 23. The brachial plexus. 24, 25. The phrenic nerve. 26. The carotid artery. 27. The internal jugular vein.

Fig. 57.



Papillæ of the Tongue.

A. Vertical section near the middle of the dorsal surface of the tongue: *a*, *a*. Fungiform papillæ. *b*. Filiform papillæ, with their hair-like processes. *c*. Similar ones deprived of their epithelium.—Magnified 2 diameters.

B. Filiform compound papillæ: *a*. Artery. *v*. Vein. *c*. Capillary loops of the secondary papillæ. *b*. Line of basement membrane. *d*. Secondary papillæ, deprived of *e*, *e*, the epithelium. *f*. Hair-like processes of epithelium capping the simple papillæ.—Magnified 25 diameters. *g*. Separated nucleated particles of epithelium, magnified 300 diameters.

1, 2. Hairs found on the surface of the tongue. 3, 4, 5. Ends of hair-like epithelial processes, showing varieties in the imbricated arrangement of the particles, but in all a coalescence of the particles towards the point. 5. Incloses a soft hair.—Magnified 160 diameters.

2. SAVOURS.

Before proceeding to explain the physiology of gustation, it may be necessary to inquire briefly into the nature of bodies as connected with their sapidity; or, in other words, into *savours*, which are the cause of sapidity.

The ancients were of opinion, that the cause of sapidity is a peculiar principle, which, according to its combination with the constituents of bodies, gives rise to various savours. This notion has been long abandoned; and chiefly, because we observe no general or common characters amongst sapid bodies, which ought to be were they pervaded by the same principle; and because bodies may be deprived of their sapidity by subjecting them to appropriate processes. Many of our culinary processes have been instituted for this purpose: the infusion of tea is indebted for all its attractions to the power we possess of separating, by boiling water, the savoury from the insipid portions of the plant. A sapid principle must, therefore, be esteemed an integrant molecule of a body; not the same in all cases, but as heterogeneous in its nature as the impressions made upon the organ of taste.

When the notion was once entertained, that a sapid principle is an integrant molecule, sapidity was attempted to be explained by its shape. It was said, for instance, that if the savour be sweet, the molecule must be round; if sharp, angular; and so forth. Sugar was said to possess a spherical,—acids, a pointed, or angular molecule. We know, however, that substances which resemble each other in the primitive shape of their crystal, impress the organ of taste differently; and that solution, which must destroy most—if not all—the influence from shape, induces no change in the savour.

Others have referred sapidity to a kind of chemical action between the molecules, and the nervous fluid. This view has been suggested by the fact, that, as a general principle, sapid, like chemical bodies, act only when in a state of solution; that the same savours usually belong to bodies possessed of similar chemical properties, as is exemplified by the sulphates and nitrates; and that, in the action of acids on the tongue and mouth, we witness a state of whiteness and constriction, indicative of a first degree of combination. All these circumstances, however, admit of another explanation. There are unquestionably many substances, which do combine chemically,—not with a nervous fluid, of whose existence we know nothing,—but with the mucus of the mouth; and the sapidity resulting from such combination is appreciated by the nerves of taste; but there are many bodies, which are eminently sapid, and yet afford us instances of very feeble powers of chemical combination; nay, in numerous cases, we have not the least evidence that such powers exist. Vegetable infusions or solutions are strong examples of the kind,—of which syrup may be taken as the most familiar. The effect of solution is easily intelligible; the particles of the sapid body are in this way separated, and come successively into contact with the gustatory organ; but there is some reason to believe, that solution is not always requisite to give sapidity. Metals have generally a peculiar taste, which has been denominated *metallic;* and this, even if the surface be carefully rubbed, so as to free it from oxide, which is more or less soluble. Birds, too, whose organs of taste are as dry as the corn they select from a mass of equally arid substances, are probably able to appreciate savours. The taste produced by touching the wires of a galvanic pile with the tongue has been offered as another instance of sapidity exhibited by dry bodies. This is, more probably, the effect of the chemical action on the fluids covering the mucous membrane of the tongue, which always follows such contact. Such chemical change must, however, be confined to these fluids; and, when once produced, the nerve of taste is impressed by the savour developed in the same manner as it is in cases of morbid alterations of the secretion of the mucous membrane. In both cases, a body possessing considerable and peculiar sapidity may fail to impress the nerves altogether, or may do so inaccurately. The notion of any chemical combination with the nervous fluid must of course be discarded, as there is not the slightest evidence in favour of the hypothesis; yet the epithet *chemical* was once applied to this sense on the strength of it; in opposition to the senses of touch, vision, and audition, which were called *mechanical,* and supposed to be produced by vibrations of the nerves of those senses.

The savours, met with in the three kingdoms of nature, are innumerable. Each body has its own, by which it is distinguished: few instances occur in which any two can be said to be identical. This is the great source of difficulty, when we attempt to throw them into classes, as has been done by physiologists. Of these classifications, the one by Linnæus[1] is best known: it will elucidate the unsatisfactory character of the whole. He divides sapid bodies into *sicca*, *aquosa*, *viscosa*, *salsa*, *acida*, *styptica*, *dulcia*, *pinguia*, *amara*, *acria*, and *nauseosa*. He gives also examples of mixed savours, *acido-acria*, *acido-amara*, *amaro-acria*, *amaro-acerba*, *amaro-dulcia*, *dulci-styptica*, *dulci-acida*, *dulci-acria*, and *acri-viscida;* and remarks, that the majority are antitheses to each other, two and two,—as *dulcia* and *acria ; pinguia* and *styptica; viscosa* and *salsa;* and *aquosa* and *sicca*. Boerhaave[2] again divides them into *primary* and *compound;* the former including the *sour*, *sweet*, *bitter*, *saline*, *acrid*, *alkaline*, *vinous*, *spirituous*, *aromatic*, and *acerb ;*—the latter resulting from the union of certain primary savours. There is no accordance amongst physiologists as to those that should be esteemed primary, and those secondary and compound; although the division appears to be admissible. The *acerb*, for example—which is considered primary by Boerhaave—is by others, with more propriety, classed among *secondary* or *compound*, and believed to consist of a combination of the acrid and acid. We understand, however, sufficiently well the character of the *acid*, *acrid*, *bitter*, *acerb*, *sweet*, &c.; but when, in common language, we have to depict other savours, we are frequently compelled to take some well-known substance as a standard of comparison.

According to M. Adelon,[3] the only distinction we can make amongst them is,—into the *agreeable* and *disagreeable*. Yet of the unsatisfactory nature of this classification he himself adduces numerous proofs. It can only, of course, be applicable to one animal species, often even to an individual only; and often again only to such individual when in a given condition. Some animals feed upon substances, that are not only disagreeable but noxious to others. The most poisonous plants have an insect which devours them greedily and with impunity: the southern planter is well aware, that this is the case with his tobacco, unless the operation of *worming* be performed in due season. The old adage, that "one man's meat is another man's poison," is metaphorically accurate. Each individual has, by organization or association, dislikes to particular articles of food, or shades of difference in his appreciation of tastes, which may be esteemed peculiar; and, in certain cases, these peculiarities are signal and surprising.

Of the strange differences, in this respect, that occur in the same individual under different circumstances, we have a forcible instance in the pregnant female, who often ardently desires substances, that were previously perhaps repugnant to her, or, at all events, not relished. The sense, too, in certain diseases—especially of a sexual character, or such as are connected with the state of the sexual functions—becomes strangely depraved, so that substances, which can in no way be ranked

[1] Amœnit. Academ., ii. 335.
[2] Prælect. Academ., tom. iv.
[3] Physiologie de l'Homme, seconde édit., i. 301, Paris, 1829.

as eatables are greedily sought after. A young lady was under the care of the author, whose *bonne bouche* was slate pencils. In other cases, we find chalk, brickdust, ashes, dirt, &c., preferred. Habit, too, has considerable effect in our decisions regarding the agreeable. The Roman liquamen or garum, the most celebrated sauce of antiquity, was prepared from half putrid intestines of fish; and one of the varieties of the Οπος Σιλφιον, *laserpitium*, is supposed to have been assafœtida.[1] Even at this day, certain orientals are fond of the flavour of this nauseous substance. Putrid meat is the delight of some nations; and a rotten egg, especially if accompanied with the chick, is esteemed by the Siamese. In civilized countries, we find game, in a putrescent state, eaten as a luxury: this, to those unaccustomed to it, requires a true education. The same may be said of the pickled olive, and of several cheeses—*fromage de Gruyère*, for example—so much esteemed by the inhabitants of continental Europe.

M. Magendie[2] asserts, that the distinction of savours into agreeable and disagreeable is the most important,—as substances whose taste appears agreeable to us are generally useful; whilst those whose taste is disagreeable are commonly noxious. As a general rule this is true, but there are many signal exceptions to it.

3. PHYSIOLOGY OF TASTE.

The physiology of taste being so nearly allied to that of touch effected by mucous membranes, it will not be necessary to repeat the uses of the various layers of which the membrane of the mouth consists. In order that taste may be satisfactorily executed, it is necessary that the membrane should be in a state of integrity; for if the cuticle be removed, gustation is not effected; and the morbid sensation of pain is substituted. It is also indispensable that the fluids poured into the cavity of the mouth should be in necessary quantity, and possess proper physical characteristics. We can farther appreciate the advantages of mastication and insalivation, by which solid bodies are divided into minute portions; dissolved when soluble, and brought successively in contact with the organ of taste. The gustatory nerves thus receive the impression, and by them it is transmitted to the brain. These nerves go to the formation of the papillæ, which, we have seen, are situate in a spongy, erectile tissue. As in the sense of tact and touch, it is probable that this erectile tissue is not passive during the exercise of taste; and that the papillæ, through it, assume a kind of erection. M. Magendie[3] believes this view to be void of foundation; but Sir C. Bell[4] has properly remarked, that if we take a pencil, dip it in a little vinegar; and touch, or even rub it strongly on the surface of the tongue, where these papillæ do not exist, the sensation of the presence of a cold liquid is alone experienced; but if we touch one of the papillæ with the point of the brush, and, at the same time, use a magnifying glass, it is seen to stand erect, and the acid taste is felt to pass, as it were backward, to the root of the tongue. This experi-

[1] See an article on the Gastronomy of the Romans, by the author, in Amer. Quarterly Review, ii. 422, Philad., 1827.

[2] Précis Elémentaire, i. 139.

[3] Précis, &c., i. 141.

[4] Anatomy and Physiol., Godman's 5th Amer. edit., ii. 283, New York, 1827.

ment confirms the one with the point of the needle before referred to, and shows that the parts of the tongue which possess the power of receiving tactile impressions are distinct from those concerned in gustation. The fine conical papillæ, by some called *filiform*, seated at the sides and tip of the tongue, have been generally esteemed the most exquisitely sensible.

The sense of taste is almost wholly accomplished in the membrane covering the tongue.[1] M. A. Vernière[2] found, in experiments which he instituted, the mucous membrane of the palatine arch, gums, cheeks, lips, and middle and dorsal region of the tongue constantly insensible to savours; whilst gustatory sensibility was possessed by the membrane covering the sublingual glands, the inferior surface, point, edges and base of the tongue; the pillars and two surfaces of the velum palati, the tonsils and pharynx. Subsequently, MM. Guyot and Admyrauld[3] found, from a series of experiments made upon themselves, that the lips, inner surface of the cheeks, palatine arch, pharynx, pillars of the velum palati, and dorsal and inferior surface of the tongue are incapable of appreciating savours; and that the seat of gustation is at the posterior and deep-seated part of the tongue, beyond a curved line, whose concavity anteriorly passes through the foramen cæcum, and joins the two margins of the tongue anterior to the pillars;—at the edges of the tongue; and on a surface of about two lines uniting them with the dorsal surface;—at the apex with an extension of four or five lines on the dorsal, and of one or two on the inferior surface; and lastly, at a small space of the velum palati situate nearly at the centre of its anterior surface. M. Guyot, moreover, found, that the same sapid body does not produce the same sensation on every part of the gustatory organ. We find, indeed, that certain bodies affect one part of the mouth, and others another. Acids act more especially on the lips and teeth; acrid bodies, as mustard, on the pharynx. These experiments were repeated by M. Longet,[4] with every precaution pointed out by MM. Vernière, Guyot, and Admyrauld. The results agreed generally with those of M. Vernière. He could not, however, discover any gustatory sensibility in the mucous membrane covering the superior surface of the velum palati, the sublingual glands and inferior surface of the tongue; and he does not regard the superior and middle region of the tongue as absolutely devoid of gustatory sensibility.

That the sense is not restricted to the tongue we have direct evidence in those cases in which the tongue has been wanting. M. Roland, of Saumur,[5] gives the case of a child, six years of age, who lost the organ in smallpox; and yet could speak, spit, chew, swallow, and taste. De Jussieu[6] exhibited to the *Académie des Sciences* of Paris, in 1718, a Portuguese girl, born without a tongue, who also possessed these faculties. In a case mentioned by M. Berdot, and cited by Rudolphi,[7] in which

[1] Bidder, Art. Schmecken, in Wagner's Handwörterbuch der Physiologie, 13ste Lieferung s. 2. Braunschweig, 1846. [2] Journal des Progrès, &c., iii. 208, and iv. 219. Paris, 1827.

[3] Mémoire sur le Siége du Goût chez l'Homme, Paris 1830, and Archives Générales de Médecine, Janvier, 1837.

[4] Traité de Physiologie, tom. ii. p. 166. Paris, 1850.

Aglossostomographie, Paris, 1630.

[6] Mém. de l'Académ. des Sciences, p. 6. Paris, 1718.

[7] Grundriss der Physiologie, 2er Band. 1ste Abtheil. s. 92. Berlin, 1823.

no part of the tongue existed, the individual could appreciate the bitterness of sal ammoniac; and the sweetness of sugar; and Blumenbach[1] refers to that of a young man, who was born without a tongue; and yet, when blindfolded, could distinguish between solutions of salt, sugar, and aloes, put upon the palate.[2]

Certain bodies leave their taste in the mouth for a length of time after they have been swallowed. This *arrière-goût*—Nachgeschmack of the Germans—is sometimes felt in the whole mouth; at others, in a part only; and is probably owing to the papillæ having imbibed the savour,—for the substances producing the effect belong principally to the class of aromatics. This imbibition frequently prevents the savour of another substance from being duly appreciated; and, in the administration of nauseous drugs, we avail ourselves of the knowledge of the fact, either by previously giving an aromatic so as to forestall the nauseous impression, or, by combining powerful aromatics with it, which strongly impress the nerves, and produce a similar result.

There is a common experiment, which has been the foundation of numerous wagers, and elucidates this subject; or at least demonstrates, that the effect produced upon the nerve by the special irritant continues, as in the case of the other senses, for some time after it has made its impression, so that the nerve becomes, for a time, comparatively insensible to the action of other sapid bodies. It consists in giving to one—blindfold—brandy, rum, and gin, or other spirituous liquors in rapid succession, and seeing whether he can discriminate one from another. A few contacts are sufficient to impregnate the nerve so completely that distinction becomes confounded.

It has been remarked, that numerous nerves are distributed to the organ of taste: the ninth pair, lingual, and other branches of the fifth, and glosso-pharyngeal. (See Fig. 56.) An interesting question arises—which of these is the nerve of taste; or are more than one, or the whole, concerned? Of old, the lingual nerve of the fifth pair was universally considered to accomplish the function; the other nerves being looked upon as simple motors. Boerhaave and others assigned the office to the ninth, and considered the others to be motors. The filaments of the fifth have been described as traceable even in the papillæ; but others have denied this. Opinions have generally settled down upon the lingual branch of the fifth pair. Such is the view of Sir Charles Bell, who considers the *ninth pair*, which arises from the anterior column of the spinal marrow, the nerve of motion for the tongue; the *lingual branch of the fifth*, a nerve having a posterior root, the nerve of taste; and the *glosso-pharyngeal*, the nerve by which the tongue is associated with the pharynx in the function of deglutition. Bellingeri[3] thinks the last nerve gives the organic and involuntary character to the tongue. In this it is aided by branches of the fifth pair and pneumogastric. The hypoglossal he regards as the nerve of the voluntary motions of the organ for articulate speech, and modulated sound in singing,—an inference which has seemed to be confirmed by the fact,

[1] Comparative Anatomy, by Lawrence, p. 323, Lond., 1807,
[2] Brillat Savarin, Physiologie du Goût, p. 38. Paris, 1843.
[3] Dissert. Inaugural. Turini, 1823, noticed in Edinb. Med. and Surg. Journal for July, 1834, p. 129.

that in fishes (*pisces muti*) it is wanting. It is likewise maintained, that the fifth is the first encephalic nerve, which appears in the lower classes of animated nature; as the taste is the first of the special senses noticed in them; that, at first, the nerve consists only of the lingual branch; and farther, that its size, in animals, is generally in a ratio with that of the organs of taste and mastication.

Certain experiments by M. Magendie[1] would seem to settle the question definitely. On dividing the lingual branch of the fifth pair on animals, he found that the tongue continued to move, but that they lost the faculty of appreciating savours. The palate, gums, and internal surface of the cheeks, however, preserved the faculty, because supplied with other branches of the fifth. But when the trunk of the nerve was cut within the cranium, the power of recognising savours was completely lost in every part of the mouth,—even in the case of highly acrid and caustic bodies. He found, too, that the loss of sense occurred in all those who had the fifth pair morbidly affected,—a fact, which has been confirmed by observations of others.[2]

Experiments on dogs by Professor Panizza, of Pavia, led him to infer, that the hypoglossal is the nerve of motion for the tongue; the lingual branch of the fifth pair, the nerve of general sensibility; and the glosso-pharyngeal, the nerve of gustation.[3] The views of Panizza have been embraced by Messrs. Elliotson,[4] Wagner,[5] Valentin, Bruns, Broughton,[6] and others, and have been recently confirmed by the experiments and observations of Stannius;[7] and Mr. Broughton has summed up what he considers to be the final results of all the comparative inquiries. The communicating nerve of the face (portio dura), and the fifth pair, arising by distinct roots, send off branches as they emerge from the bed of the parotid gland, some of which unite in parallel lines, and others do not, each ramification retaining the original property of its own root unmixed; the one destined to govern certain motions of different parts of the face; the other devoted to tactile sensibility, as far as regards the superficial parts of the face. Thus far, there is no disagreement: the whole development has been arrived at by repeated experiments by different persons. In the next place, it appears, that the hypoglossal governs the motions of the tongue; deglutition; and mastication, without interfering with common sensation and taste. The instinctive and voluntary motions of the tongue are all destroyed by dividing this nerve. The next position is, that the lingual branches of the fifth pair are devoted to tactile sensibility, or the common sensation

[1] Précis., i. 144, and Journal de Physiologie, t. iv.

[2] Mr. Bishop, in Lond. Med. Gazette for Dec. 12, 1835; and Romberg, Müller's Archiv., 1838, H. iii.

[3] Ricerche Sperimentali sopra i Nervi, translated in Edinb. Med. and Surg. Journal, for Jan., 1836, p. 70; see also, Amer. Journal of the Med. Sciences, May, 1836, p. 188; and Mayo, Outlines of Human Physiology, 4th edit., p. 314, London, 1837.

[4] Human Physiology, p. 536, Lond. 1840.

[5] Traité de Névrologie, trad. par Jourdan, p. 433, Paris, 1843, and Lehrbuch der Physiologie des Menschen, ii. 679. Braunschweig, 1844.

[6] Edinburgh Medical and Surgical Journal, April, 1836, p. 431. A case in which there was complete insensibility of every part supplied by the fifth pair, and the sense of taste was perfect, is given in Bullet. dell Scienz. Medich., Aprile, 1841, cited in Brit. and For. Med. Rev., Oct., 1842, p. 545. See, also, Bidder, Art. Schmecken, in Wagner's Handwörterbuch der Physiologie, loc. cit.

[7] Müller's Archiv., s. 132–138, Berlin, 1848.

of the tongue. Their division does not affect the motions of that organ or its power of taste; both remain entire. Lastly, when the glosso-pharyngeal nerve is divided, the sense of taste is lost; whilst, the other nerves being uninjured, motion and tactile sensibility remain. Professor Panizza found, that when the glosso-pharyngeal nerves were divided, the animal could not taste coloquintida.

From a series of experiments, however, similar to those of Panizza and Mr. Broughton, Mr. Mayo inferred, in conformity with an opinion previously expressed by him,[1] that the lingual branch of the fifth is the proper nerve of taste, and that it possesses also general sensibility; that the ninth or hypoglossal is the nerve of voluntary motion; whilst the glosso-pharyngeal is in part a nerve of voluntary motion and in part of general sensibility, but not of taste.[2] Again: the experiments and researches of Dr. John Reid,[3] have satisfied him, that after the perfect section of the glosso-pharyngeal nerves on both sides, the sense of taste is sufficiently acute to enable the animal to recognise bitter substances; and his inference is, that this nerve may participate with others in the function of taste; but that it assuredly is not the special nerve of that sense. Prof. J. Müller[4] esteems it certain, both from his own experiments and those of M. Magendie and others, as well as from pathological observations, that the lingual branch of the fifth is the principal nerve of taste of the tongue; but he does not regard it proved, that the glosso-pharyngeal has no share in the perception of taste at the posterior part of the tongue, and in the fauces. Dr. Carpenter,[5] from a consideration of how nearly the sense of taste is allied to that of touch, and bearing in mind the distribution of the two nerves, thinks it not difficult to arrive at the conclusion, that both nerves are concerned in the function;[6] and that there seems good reason to believe the glosso-pharyngeal to be exclusively that through which the impressions made by disagreeable substances taken into the mouth are propagated to the medulla oblongata, so as to produce nausea, and excite efforts to vomit;—whilst M. Longet[7] regards the lingual branch of the fifth and the glosso-pharyngeal as necessary for the general and special sensibility of the gustatory organs, "the action of the one perfecting that of the other, both as respects the general sensibility and the gustatory sensibility of the tongue." It may be proper to add, that experiments seem to show, that the glosso-pharyngeal possesses also a direct motor influence. Such is the inference of Messrs. J. Müller, Volkmann, and Hein. The last observer, whose experiments were carefully performed, states that his results accord completely with those of Volkmann. When the roots of the glosso-pharyngeal nerve were irritated in the recently cut-off heads of calves and dogs, after removing the brain and medulla ob-

[1] Anatomical and Physiological Commentaries, p. 2, Lond., 1822.

[2] Bostock's Physiology, 3d edit., p. 732, Lond., 1836; and Mayo, Outlines of Physiology, 4th edit., p. 314, Lond., 1837.

[3] Edinburgh Medical and Surg. Journal, for Jan., 1838, p. 129. See, on this disputed topic, Alcock, in Dublin Journal, for Nov., 1836, and J. Guyot, Archives Générales de Médecine, Janvier, 1837.

[4] Elements of Physiology, by Baly, P. v. p. 1321, Lond., 1839.

[5] Human Physiology, p. 173, and p. 253, Lond., 1842.

[6] Todd and Bowman, The Physiological Anatomy and Physiology of Man, p. 442, London, 1845.

[7] Traité de Physiologie, ii. 297, Paris, 1850.

longata, and separating their roots from those of the pneumogastric, contractions always ensued in the stylo-pharyngeus muscle. From all the facts adduced by recent observers, Mr. Paget[1] thinks it probable,—*First.* That the glosso-pharyngeal is chiefly the nerve of taste, and, in a less degree, a nerve of common sensation; and *Secondly.* That, according to the experiments of MM. Müller and Hein, it is the motor nerve of the stylo-pharyngeus, and probably also of the palato-glossus.

Lastly, M. de Blainville supposes, that the sense of taste is, perhaps, neither sufficiently special nor sufficiently limited in extent to have a separate nervous system; and therefore that all the nerves of the tongue are equally inservient to the sense, as the different nerves of the skin, which proceed from numerous pairs, are equally inservient to touch or tact.[2]

Such is the existing state of uncertainty regarding this interesting point of physiology: the view of Panizza appears, however, to the author, to be most in accordance with analogy; and in all respects most worthy of adoption. From the experiments and observations of Bellingeri, Montault, Diday, C. Bernard, and Verga,[3] it would appear, that the filaments of the chorda tympani, which are united and confounded with those of the lingual branch of the fifth pair, are in an inexplicable manner connected with gustation. When the facial nerve has been paralyzed, or divided above the origin of the tympanic branch, the sense of taste has been impaired. The functions of the chorda tympani are by no means determined;—some esteeming it as a sensory, others as a motor nerve; whilst others, again, believe it to possess both sensory and motor properties.

The immediate function of taste, as has been remarked, is to give the sensation of savours. This function, like touch, is instinctive; requires no education; cannot be supplied by any of the other senses, and is accomplished as soon as the tongue has acquired the necessary degree of development. To this it may be replied, that the very young infant is not readily affected by savours. In all cases, however, certain sapid bodies excite their usual impression; and, in the course of a few months, when the organ becomes developed, the sense acquires a high, and often inconvenient, degree of acuteness.

The mediate or auxiliary offices of gustation are few, and limited in extent. It does not afford much instruction to the mind. The chemist and mineralogist occasionally gain information through it; but it is never considered to merit the rank of an *intellectual* sense: on the contrary, it is classed with olfaction as a *corporeal* sense.

To appreciate a savour accurately, the sapid substance must remain for a time in the mouth: when rapidly swallowed, the impression is feeble, and almost null. Of this fact we take advantage when compelled to swallow nauseous substances; whilst we retain a savoury article long in the mouth, in order that we may extract its sweets. How different, too, is the consent of the auxiliary organs under these two circumstances! Whilst a luscious body augments the secretion of the

[1] Brit. and For. Med. Rev., April, 1845, p. 580.
[2] Adelon, op. cit., i. 309.
[3] Cited by M. Longet, op. cit., p. 365, Paris, 1850.

salivary glands, or causes the "mouth to water," as it has been called—projecting the saliva, at times, to a distance of some feet from the mouth, and disposing every part to approach or mingle with it—a nauseous substance produces constriction of every secretory organ; an effect which extends even to the stomach itself, so that it often rejects the offending article, as soon as it reaches the cavity. We can thus understand how, *cæteris paribus*, an article, that is pleasing to the palate, may be more digestible than one that excites disgust; and conversely. Of the "consent of parts," exerted between the stomach and the organ of taste, we have a familiar illustration in the fact,—that whatever may be the *goût*, with which we commence a meal on a favourite article of diet, we find that the relish is blunted as the stomach becomes filled; and hence the Romans were in the habit of leaving the table once or twice during a meal, and, after having unloaded the organ, of returning again to the charge—"*vomunt ut edant, edunt ut vomant.*"

If we place a sapid substance in the mouth, and then close the nostrils, the taste is diminished,—a fact, which has given rise to the generally prevalent and correct opinion, that an intimate relation exists between the smell and taste. They are, however, distinct. Most sapid substances have an odour or "flavour," which is not appreciated when we prevent the air from passing through the nasal fossæ. This renders the impression on the gustatory nerves still less marked, but it exists. Gustation is likewise diminished by the new sensation produced in the nostrils by their closure; so that the same amount of attention is not directed to the sense of taste.

Among animals we see great diversities in this sense. Whilst none possess the refined taste of man; there are many, which are capable, by taste or smell, of knowing plants that are nutritive from those that are noxious to them; and it is unusual for us to find that an animal has died from eating such as are unquestionably poisonous to it. Yet, as we have remarked, a substance, that is noxious to one, may be eaten with impunity by another; and, if we select animals, and place them in a field containing plants, all of which are ranked as poisons, and are poisonous to a majority of them, we find that not only has a selection been made by each animal of that which is innocuous to it, but that the substance has furnished nourishment to it, whilst it might have proved fatal to others. All this must be dependent upon peculiar, and inappreciable organization.

The sense of taste is more under the influence of volition than any other. It is provided with a muscular apparatus, by which it can be closed or opened at pleasure; and, in addition, ordinarily requires the assistance of the upper extremity to convey the sapid substance to the mouth. The sense can, therefore, be exercised either *passively* or *actively;* and, by cultivation, it is capable of being largely developed. The spirit taster to extensive commercial establishments exhibits the truth of this in a striking manner. In his vocation, he has not only to taste numerous samples, but to appreciate the age, strength, flavour, and other qualities of each: and the practised individual is rarely wrong in his discrimination. With almost all, if not all, these "tasters," the custom is to take a small quantity of the liquor into the mouth; throw

it rapidly around that cavity, and eject it. A portion, in this way, comes in contact with every part of the membrane; and of course impresses not only the lingual, but the other ramifications of the fifth pair.

The *gourmet* of the French—somewhat more elevated in the scale than our ordinary epicure—prides himself upon his discrimination of the nicest shades of difference and excellence in the materials set before him. Many *gourmets* profess to be able to pronounce, by sipping a few drops of wine, the country whence it comes, and its age; and, according to Stelluti, can tell, by the taste, whether birds put upon the table are domesticated or wild,—male or female.[1] Dr. Kitchener[2] asserts, that many epicures are capable of saying in what precise reach or stretch of the Thames the salmon on the table has been caught, and Sir Astley Cooper was in the habit of relating the remarkable case of a professional friend, who could discriminate by the taste the beef furnished by a particular London butcher.[3]

This acuteness of sense is by no means desirable. Doomed to meet, in his progress through life, with such a preponderance of what demands obtuseness rather than acuteness of feeling, the epicure must be liable to continual annoyances and discomforts, which the less *favoured* can never experience.

In disease, gustation often becomes greatly depraved; and the various morbid tastes have been accounted for by depraved secretions in the mouth, acting as foreign sapid substances on the papillæ. Certain tastes, however, cannot be explained in this way, and must be regarded as nervous phenomena. If the epithelium be covered with a fur, taste may be lost or impaired, and be instantaneously restored as soon as the coating is removed. M. Magendie observed, that dogs, after the injection of milk into their veins, licked their lips, and gave other evidences of tasting. When Dr. E. Hale, in an experiment referred to in another part of this work, injected castor oil into one of his veins, he distinctly tasted the oil a short time afterwards. Messrs. Todd and Bowman[4] suggest that such phenomena, if uniformly present, might be occasioned by the transudation of the fluid from the vessels to the nerves of the papillæ; and this may be the true explanation, although it is not easy to see that such transudation could occur in the case of castor oil.

SENSE OF SMELL OR OLFACTION.

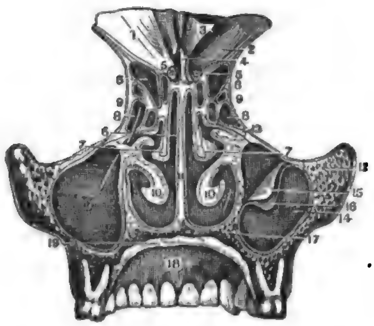
The object of this sense is to appreciate the odorous properties of bodies. It differs from the last in the circumstance that the body does not come into immediate contact. It is only necessary that an odorous emanation from it shall impinge upon the organ of sense. Still, it does not essentially vary in its physiology from the sense of taste.

1. ANATOMY OF THE ORGAN OF SMELL.

The organ of smell is a mucous membrane, which lines the nasal cavities, and is called *Schneiderian* or *pituitary*. It resembles that which covers the organ of taste, except that the nervous papillæ are more delicate, to correspond with the greater tenuity of the body that

[1] American Quarterly Review, ii. 427. [2] Cook's Oracle, 3d edit., p. 229, Lond., 1821.
[3] Life of Sir Astley Cooper, Bart., by Bransby Blake Cooper, Esq., F. R. S., ii. 137, Lond., 1843.
[4] The Physiological Anatomy and Physiology of Man, p. 448, Lond., 1845.

Fig. 58.



Vertical Section of the Middle Part of the Nasal Fossæ, giving a Posterior View of the Arrangement of the Ethmoidal Cells, &c.

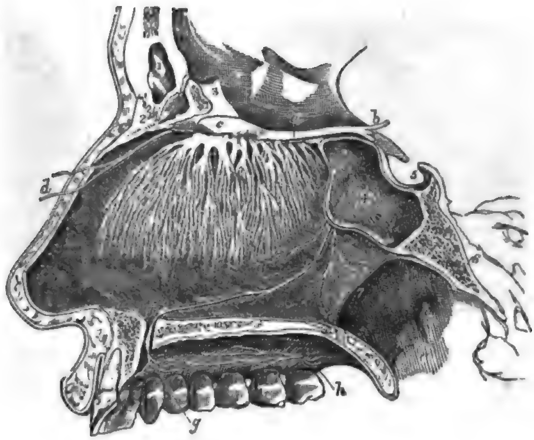
1. Anterior fossæ of the cranium. 2. The same covered by the dura mater. 3. Dura mater turned up. 4. Crista galli of the ethmoid bone. 5. Its cribriform plate. 6. Its nasal lamella. 7. Middle spongy bones. 8. Ethmoidal cells. 9. Os planum. 10. Inferior spongy bones. 11. Vomer. 12. Superior maxillary bone. 13. Its union with the ethmoid. 14. Anterior parietes of the antrum Highmorianum, covered by its membrane. 15. Its fibrous layer. 16. Its mucous membrane. 17. Palatine process of the superior maxillary bone. 18. Roof of the mouth, covered by the mucous membrane. 19. Section of this membrane. A bristle in the orifice of the antrum Highmorianum.

has to make the impression. The membrane lines the whole of the bony cavities called *nasal fossæ*, which are constantly open anteriorly and posteriorly, to permit the air that traverses them to proceed to the lungs. The anterior aperture is covered by a kind of pent-house or capital, for the purpose of collecting the odorous particles. This capital is called the *nose*. The essential part of the organ is the pituitary or olfactory membrane,—the other parts being superadded to perfect the sense.

The bony portions of the nose are separated from each other by the *vomer*. This bony septum is prolonged, by means of cartilage, to the anterior extremity of the nose, so that the nasal fossæ are divided into like parts, which have no communication with each other, but open together, posteriorly, into the top of the pharynx. Within each of the nares are two *convoluted* or *turbinated bones*—generally called *ossa spongiosa* vel *turbinata;* and, by the French, *cornets*. These are situate one above the other; the *superior* formed of a plate of the ethmoid bone—the inferior a distinct bone. They divide the general cavity of each nostril into three *passages* or *meatus*. The *inferior* meatus is broad and long; the least oblique, and least tortuous; the *middle* is narrow, almost as long, but more extensive from above to below; and the *superior* is much shorter, more oblique, and still narrower. The narrowness of these passages in the living subject is so great, that the slightest tumefaction of the membrane renders the passage of air through the fossæ extremely difficult. This is the cause of the difficulty of breathing through the nose, that attends "a cold in the head." Into the two upper passages, cavities in certain bones open, which considerably enlarge the extent of the fossæ. These are called *sinuses;* and are the *maxillary*, *palatine*, *frontal*, *sphenoidal*, *ethmoidal*,—the last being sometimes termed *ethmoidal cells*.

All the cavities are lined by the delicate pituitary membrane, or by a prolongation of it. In the nasal fossæ it augments the thickness of the turbinated bones. It resembles the mucous membranes in general in its composition; and adheres firmly to the bones and cartilages, which it covers. Its aspect is velvety, owing to a multitude of minute papillæ; and it receives a great number of vessels and nerves. The sinuses are lined by a prolongation apparently of the same membrane, differing, however, in some respects from the other. The whole of the

Fig. 59.



View of the Olfactory Nerve, with its Distribution on the Septum Nasi. The nares have been divided by a longitudinal section made immediately to the left of the septum, the right nares being preserved entire.

1. The frontal sinus. 2. The nasal bone. 3. The crista galli process of the ethmoid bone. 4. The sphenoidal sinus of the left side. 5. The sella turcica. 6. The basilar process of the sphenoid and occipital bones. 7. The posterior opening of the right nares. 8. The opening of the Eustachian tube in the upper part of the pharynx. 9. The soft palate, divided through its middle. 10. Cut surface of the hard palate. *a*. The olfactory peduncle. *b*. Its three roots of origin. *c*. Olfactory ganglion, from which the filaments proceed that spread out in the substance of the pituitary membrane. *d*. The nasal nerve, a branch of the ophthalmic nerve, descending into the left nares from the anterior foramen of the cribriform plate, and dividing into its external and internal branch. *e*. The naso-palatine nerve, a branch of the spheno-palatine ganglion distributing twigs to the mucous membrane of the septum nasi in its course to (*f*) the anterior palatine foramen, where it forms a small gangliform swelling (Cloquet's ganglion) by its union with its fellow of the opposite side. *g*. Branches of the naso-palatine nerve to the palate. *h*. Posterior palatine nerves. *i*, *i*. The septum nasi.

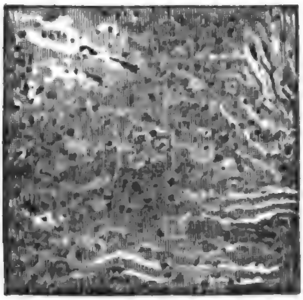
membrane is the seat of the secretion of *nasal mucus*, which, doubtless, performs a part in olfaction as important as the secretion from the mucous membrane of the mouth does in gustation.

The same nerve is not distributed over the whole of this membrane. In some parts, the *olfactory*, *ethmoidal*, or *first pair* can be traced; in others, we see only filaments of the fifth pair. The first of these have not always been regarded as the nerves of smell. Anciently, they were presumed to be canals for the passage of pituita or phlegm, which was supposed to be secreted by the brain. At the present day, anatomists are doubtful only as regards their origin; some deriving them from the anterior lobes of the brain; others from the corpora striata, which have, in consequence, been called *thalami nervorum ethmoïdalium;* and others, again, with Willis and Gall,[1] and with probability, referring them, like every other nerve of sense, to the medulla oblongata. M. Béclard affirms, that in a hydrocephalic patient, where a part of the brain had been destroyed by disease, he actually saw this origin.[2] The nerve proceeds directly forwards until it reaches the upper surface of the cribriform plate of the ethmoid bone, where it divides into a number of filaments, that pass through the foramina in the plate, and attain the nasal fossæ; where they are dispersed on the upper and middle part of the Schneiderian membrane; but cannot be traced on the lower. Most anatomists are of opinion, that here they constitute, with vessels of exhalation and absorption, the papillæ; whilst others, as Scarpa, not having been able to trace them thither, have been of opinion, that the filaments interlace to constitute a kind of proper membrane. Our

[1] Recherches sur le Système Nerveux en général et sur celui du Cerveau en particulier, par F. J. Gall et G. Spurzheim, Paris, 1809.

[2] Adelon, Physiologie de l'Homme, edit. cit., i. 330.

Fig. 60



A portion of the Pituitary Membrane of the Nasal Septum, magnified 9 times, showing the Number, Sizes, and Arrangement of the Mucous Crypts.

Fig. 61.

A portion of the Pituitary Membrane with its Arteries and Veins injected.—Magnified 15 diameters.

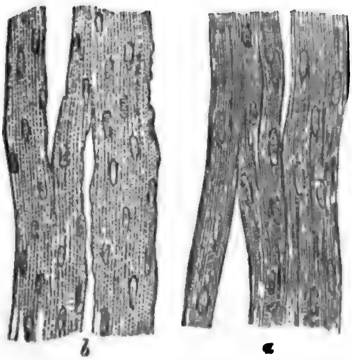
The natural size of this piece is seen at the bottom of the cut.

1, 1, 1. Orifices of three mucous crypts surrounded by veins and arteries.

means of observation cannot be considered sufficient to enable us to decide this question positively. The nerve has not been traced on the os spongiosum inferius; on the inner surface of the middle spongy bone, or in any of the sinuses.

The olfactory filaments, according to Messrs. Todd and Bowman,[1] form a considerable part of the entire thickness of the Schneiderian membrane, and differ widely from the ordinary encephalic nerves in structure. They contain no *white substance of Schwann;* are not divisible into elementary fibrillæ; are nucleated and finely granular in texture, and invested with a sheath of homogeneous membrane; and are regarded by those gentlemen as direct continuations of the vesicular matter of the olfactory bulb or ganglion; and they "venture to hint," that the amalgamation of the elements of the peripheral part of the nervous apparatus in the larger branches, and probably in the most remote distribution, as well as the nucleated character indicative of an essential continuity of tissue with the vesicular matter of the lobe, are in accordance with the oneness of the sensation resulting from simultaneous impressions on different parts of this organ of sense, and seem to show, that it would be most correct to speak of the first pair of nerves as a portion of the nervous centre put forward

Fig. 62.



Olfactory Filaments of the Dog.

a. In water. *b*. In acetic acid.—Magnified 260 diameters.

[1] Op. cit., ii. 5-11.

beyond the cranium, in order that it may there receive, as at first hand, the impressions of which the mind is to become cognizant.

Besides the first pair of nerves, the pituitary membrane receives several branches from the fifth encephalic pair; for example, the nasal twig of the ophthalmic branch of the fifth, and filaments from the frontal branch of the same; from the spheno-palatine ganglion; the palatine nerve; the vidian nerve; and from the anterior dental branch of the superior maxillary. One of these twigs enters the anterior naso-palatine canal; and, in its course to the roof of the mouth, passes through a small ganglion, which has been described by M. H. Cloquet under the name *naso-palatine*, and which he conceives to be the organ of sympathy between the senses of smell and taste.

The pituitary membrane is kept moist by nasal mucus, as well as by the exhalation that constantly takes place from it. It receives the superfluous tears by means of the ductus ad nasum,—a duct passing from the inner canthus of the eye, and opening into the nasal fossæ below the lower spongy bone. The constant evaporation which must take place from the membrane, owing to the passage of the air during respiration, requires that the secretion should be continuous and copious, otherwise the membrane would become dry.

The nasal fossæ communicate externally by means of the nostrils, the shape, size, and direction of which vary, so as to give rise to the *aquiline*, *Roman*, *pug*, and other varieties of nose. At the extremity of the nostrils long hairs are situate—technically called *vibrissæ*—whose function, it is conceived, may be to sift, as it were, the air passing through during respiration, and thus prevent extraneous bodies from entering the fossæ. The nostrils are also capable of being expanded or contracted by appropriate muscles.

In this sense, there is a more clear separation between the physical and nervous part of the apparatus than in either of those already considered;—the nose proper forming the physical portion; and the nerves of smell the organic or nervous.

2. ODOURS.

The comprehension of the physiology of olfaction will not be complete without an inquiry into *odours*, or those emanations from odorous bodies, that give them their character, and impress the organ of smell.

It was long maintained, as in the case of savours, that odours are dependent upon a peculiar principle, which, according to its particular combination with the constituents of bodies, gives rise to various odours. To this principle the terms *aroma* and *spiritus rector* have been assigned; but the notion has been long abandoned, because no general or common characters are observable amongst odorous bodies, which should be expected were they indebted for their odour to the same principle. Walther, a German physiologist, expresses the opinion, that an odorous body is such by virtue of a vibratory motion, analogous to that made by a sonorous body. We have, however, the most satisfactory evidence, that there are special odours, as there are special savoury molecules. We can prevent an odorous body from impressing our olfactory nerves by covering it with a glass receiver. Odours can be separated by in-

fusion and distillation. The fact, moreover, has been directly proved by an experiment of M. Berthollet. On nearly filling a tube with mercury, and placing a piece of camphor at the top of the tube, he found that, after a time, the mercury descended, the camphor had diminished in size, and the space above the metal was occupied by an odorous gas.[1]

But what is the cause of the disengagement of these odorous molecules? By most writers on this subject it has been considered to be owing to the solvent action of caloric on the odorous body. The opinion that all bodies are odorous is as old as Theophrastus; and it is one which it is difficult not to embrace, if we add—provided they are subjected to the appropriate agents for disengaging the odorous particles; and the probability is, that the reason we esteem particular bodies inodorous is, that our olfactory nerves are not organized with sufficient delicacy to enable us to distinguish their odorous properties. Heat assists the escape of odorous particles from a variety of bodies; and hence it has been maintained, that every body which is volatile must be odorous. M. Adelon[2] asserts, that this is not the case; but it is difficult to accord with him. The fact of our not appreciating the odour is no proof of its non-existence. In truth, bodies that are inodorous to one animal or individual may not be so to another. In cases, too, in which smell is morbidly acute, a substance may appear overwhelmingly odorous, which may appear devoid of smell to a healthy individual. M. H. Cloquet[3] refers to the case of a celebrated Parisian physician, who was subject to violent attacks of hemicrania or megrim, and who was dreadfully tormented, during one of the paroxysms, by the smell of copper, exhaled from a pin that had been dropped on the bed!

Caloric seems to be only one of the causes of the disengagement of odours. Some are retained by so feeble a degree of affinity, that they appear to be exhaled equally at all temperatures. Light influences their escape in particular cases; some plants giving off their fragrance during the day; others perfuming the air only at night. Dampness, in many instances, assists their escape,—hence the fragrance of a garden after a summer's shower; and the smell afforded by all argillaceous substances when breathed upon,—a fact, the knowledge of which is of importance to the chemist.

Lastly;—substances, that appear to us devoid of odour, may exhale a strong one, when rubbed together. All these circumstances tend greatly to prove, that every substance is possessed of odorous qualities, although we may not be aware of the precise mode for causing their emanation, or our olfactory nerves may not be sufficiently delicate to appreciate them.

Around odorous bodies, the molecules, as they escape, form an atmosphere, which, of course, will be denser, the nearer it is to the body. These particles are diffused around,—not, probably, in the same manner as light or sound, but as one fluid mixes with another; and, when the air is still, it is conceived, their strength will be inversely as the

[1] Cloquet, Art. Odeurs, Dict. des Sciences Médicales, tom. xxxvii., p. 89, Paris, 1819.
[2] Op. cit., i. 322.
[3] Osphrésiologie ou Traité des Odeurs, Paris, 1821.

square of the distance from the substance that exhales them. There is a great difference, however, in odours as regards their diffusibility in the atmosphere. Some extend to a great distance, whilst others are confined within a small compass. The odours of many flowers are so delicate as not to be appreciated, unless they are brought near the olfactory organs; whilst that of cinnamon is said to have been detected at sea, at the distance of twenty-five miles from Ceylon. Lord Valentia[1] affirms, that he himself distinctly smelt the aromatic gale at nine leagues' distance;—but Dr. Ruschenberger[2] was not equally fortunate. The author was informed by Commodore Stewart, of the Navy, that he had discovered the spicy emanations when two hundred miles from Ceylon; and the terebinthinate odours of the pines of Virginia, when one hundred miles from the coast; and the author's friend, Dr. Wilcocks, of Philadelphia, when at sea in 1844, and two hundred miles to the westward of the coast of Ireland, observed, as did many others of the passengers, a smoky odour, which lasted for several days in succession. On appealing to the captain for the cause of the phenomenon, he informed them that he had frequently remarked it before; and that it was owing to the long continuance of easterly winds, which carried the odour of burning peat from Ireland far out to sea.[3] Facts of this kind are employed by the natural philosopher to exhibit the excessive divisibility of matter. Scales, in which a few grains of musk have been weighed, have retained the smell for twenty years afterwards, although they must have been constantly exhaling odorous molecules during the whole of this period. Haller[4] kept some papers, for more than forty years, which had been perfumed by a single grain of amber; and, at the end of that time, they did not appear to have lost any of their odour. That distinguished physiologist and mathematician calculated, that every inch of their surface had been impregnated by $\frac{1}{2891108410000}$th of a grain of amber, and yet they had scented for 14,600 days a stratum of air at least a foot in thickness. But how much larger must these molecules be than those of light—provided we regard it as consisting of molecules—seeing that glass is capable of arresting the former, but suffers the other to penetrate it in every direction.

Nor need we be so much surprised at the excessive diffusibility of odorous particles, when we call to mind the facts on record in regard to the transmission through the air of fine particles of sand. Generally, according to Mr. Darwin,[5] the atmosphere of the Cape Verd Islands is hazy; and this is caused by the falling of impalpably fine dust, which was found to have slightly injured the astronomical instruments. The morning before they anchored at Porto Praya, he collected a little packet of this brown-coloured fine dust, which appeared to have

[1] Voyages and Travels in India. London, 1809.
[2] Embassy to the courts of Muscat and Siam, &c., p. 154. Philad., 1838.
[3] Medical Examiner, March, 1846, p. 159.
[4] Elementa Physiolog., tom. v. lib. xiv. sect. 2, p. 157. Lausann., 1769.
[5] Journal of Researches into the Natural History and Geology of the countries visited during the voyage of H. M. S. Beagle round the world, &c. Amer. edit., i. 5. New York, 1846.

been filtered from the wind by the gauze of the vane at the mast-head. Sir Charles Lyell also gave him four packets of dust which fell on a vessel a few hundred miles northward of these islands. Professor Ehrenberg found, that this dust consisted, in great part, of infusoria with silicious shields, and of the silicious tissue of plants. In five little packets which Mr. Darwin sent him, he ascertained no less than sixty-seven different organic forms! The infusoria, with the exception of two marine species, were all inhabitants of fresh water.

Mr. Darwin has found no less than fifteen different accounts of dust having fallen on vessels when far out in the Atlantic. From the direction of the wind whenever it has fallen, and from its having always been observed during those months when the harmattan is known to raise clouds of dust high in the atmosphere, it is pretty certain that it must proceed from Africa. It is, however—as Mr. Darwin remarks—a singular fact, that, although Professor Ehrenberg is acquainted with many species of infusoria peculiar to Africa, he found none of these in the dust sent him; but, on the other hand, discovered in it two species which he knew as living only in South America. "The dust," says Mr. Darwin—"falls in such quantity as to dirty everything on board, and to hurt people's eyes; vessels even have run on shore owing to the obscurity of the atmosphere. It has often fallen on ships when several hundred, and even more than a thousand miles from the coast of Africa, and at points sixteen hundred miles distant in a north and south direction. In some dust, which was collected on a vessel three hundred miles from the land, I was much surprised to find particles of stone above the thousandth of an inch square, mixed with finer matter. After this fact, one need not be surprised at the diffusion of the far lighter and smaller sporules of cryptogamic plants."

The air is not the only vehicle for odours. It has been seen, that they adhere to solid bodies; and that, in many cases, they can be separated by aqueous or spirituous distillation. The art of the perfumer consists in fixing and preserving them in the most agreeable and convenient vehicles. Yet, it was at one time strenuously denied, that they could be conducted through water; and, as a natural consequence of this, that fishes could smell. M. Duméril, for example, maintained, that odours, being essentially of a volatile or gaseous nature, cannot exist in fluids;—and, moreover, that fishes have no proper olfactory organ;—that the part which is commonly considered in them to be such is the organ of taste. This opinion is entertained by few. We have seen that odours can be retained in fluids, and not many naturalists of the present day will be hardy enough to deny that fishes have an organ or sense of smell. At all events, few anglers, who have used the oil of rhodium, or other attractive bait, will be disposed to give up the results of their experience without stronger grounds than any that have been assigned by the advocates of that view of the subject. Besides, air is contained in considerable quantity in water, so that odorous substances might reach the olfactory organs through it.

When it was determined, that odours consist in special molecules given off from bodies, it was attempted to explain their action on the pituitary membrane in the same manner as that of savours on the

membrane of the tongue. It was conceived that the shape of the molecules of a pungent odour is pointed, that of an agreeable one, round. Others, again, were of opinion, that olfaction is owing to some chemical union between the odorous molecule and the nervous fluid, or between it and the nasal mucus. None, however, have attempted to specify the precise chemical composition that renders a body odorous. The sensations do not present the most favourable occasions for exhibiting chemical agency; and, in this particular sense, it is probably no farther concerned than in the sense of touch; and not so much as in that of taste. It is sufficient for the odorous particle—animal, vegetable, or mineral—to come in contact with the olfactory nerves, in order that the odour shall be appreciated; and we may, in vain, look for chemical action in many of those animal and vegetable perfumes,—as musk, amber, camphor, vanilla, &c.—which astonish us by their intensity and diffusibility.

The same remarks, that were made on the classification of savours, are applicable to that of odours. They are not less numerous and varied; and each substance, as a general rule, has its own, by which it is distinguished. Numerous attempts have been made to group them; but all have been unsatisfactory. The classification proposed by Linnæus,[1] was—into *Odores aromatici*, those of the flowers of the pink, bay leaves, &c.; *O. fragrantes*, those of the lily, jessamine, &c.; *O. ambrosiaci*, those of amber, musk, &c.; *O. alliacei*, those of garlic, assafœtida, &c.; *O. hircini*, (like that of the goat,) those of the *Orchis hircina*, *Chenopodium vulvaria*, &c.; *O. tetri*, *repulsive* or *virous*,—those of the greater part of the family *solaneæ;* and lastly, *O. nauseosi*, those of the flowers of the veratrum, &c. A simple glance at this division will exhibit its glaring imperfections. No two persons could agree to which of any two of the cognate classes a particular odour should be referred. None of the other classifications, that have been proposed, are more satisfactory. M. Fourcroy divided them into *extractive* or *mucous*, *fugaceous oily*, *volatile oily*, *aromatic* and *acid*, and *hydrosulphureous;*—and Lorry into *camphorated*, *narcotic*, *ethereal*, *volatile acid*, and *alkaline*. The distinction into *animal*, *vegetable*, and *mineral*, is not more commendable. Musk is the product of an animal of the ruminant family; but the odour is not confined to that animal. It is contained in the civet; in the flesh of the crocodile; and in the musk-rat. Haller asserts, that his own perspiration smelt of it. It is met with, likewise, in the vegetable kingdom;—in *Erodium moschatum*, in the seeds of *Abelmoschus*, the flowers of *Rosa moschata*, and *Adoxa moschatellina*, and in some of the varieties of the melon and pear; and, what is perhaps more surprising, in mineral substances;—as in certain preparations of gold; and in some earths of which tea-pots are made in China and Japan. The odour of garlic, again, is found not only in that vegetable, but in assafœtida, in arsenic, when thrown upon hot coals; and in *Bufo pluvialis*, a species of toad.

In by far the majority of cases, we can only designate an odour by

[1] Amœnitat. Academic. Erlang., 1787, 1790.

comparing it with that of some well-known substance; hence the epithets *musky*, *alliaceous*, *spermatic*, &c. M. Adelon asserts, that the sole classification which can be adopted, is into the *agreeable* and *disagreeable*. But even the miserably imperfect division proposed by Haller[1] is better than this: he made three classes—*Odores suaveolentes*, *O. medii*, and *O. fœtores*. The truth is, that all the objections made to the division of savours into *agreeable* and *disagreeable*, are equally applicable to odours. Assafœtida, we have seen, was employed by the ancients as a condiment; and, although with us it has the name *devil's dung*, it is by many of the Asiatics, called *food of the gods*. We find, too, certain animals that are almost enchanted by particular odours. The cat, for example, if catmint—*Nepeta cataria*,—or the root of valerian—*Valeriana officinalis*—be placed in its way. Again, odours, generally thought agreeable, are to some persons intolerable. To many, as to Professor Müller,[2] mignonette has but an herb-like odour. The smell of the callicanthus is to most individuals pleasant; but exceedingly disagreeable to some; and, according to Arnold,[3] whilst the flower of *Iris Persica* was pronounced to possess an agreeable odour by forty-one out of fifty-four persons, four considered it to have little scent; by eight it was declared to be devoid of odour, and by one to be disagreeable. These differences, like those in the appreciation of savours by animals, must be referred to minute and inappreciable differences of organization.

Odours have been considered to be possessed of medicinal and even of poisonous properties. Some individuals, whose peculiarity of constitution renders them very liable to the action of ipecacuanha or jalap, experience the emetic effects of the former, or the cathartic qualities of the latter, by merely smelling them for a short time; and the majority of individuals, by pounding jalap or rhubarb find themselves sooner or later more or less affected. By smelling strong alcohol for a considerable time, intoxication may be induced, as not unfrequently happens to the spirit-taster, who is young in his vocation. It has also been asserted, that the constant application of this sense to the discrimination of teas in the English East India Company's warehouses has laid the foundation for numerous head affections; but the report originated in prejudice, or in accidental coincidences, and has not been found to be accurate.

In all cases in which we see medicinal or poisonous effects actually produced by substances inhaled through the nostrils, we cannot attempt to explain them by the simple impression made by the odorous particles on the olfactory nerves. They must be accounted for by minute particles of the medicinal or poisonous substance being diffused in the atmosphere, and coming in contact with the mucous membrane, through which they are absorbed, and in this manner enter the circulation.

Odours have, likewise, been considered to possess nutritive properties; and this, chiefly, perhaps, from the effect known to be produced

[1] Elementa Physiolog., tom. v. lib. xiv. p. 162, Lausann., 1769.
[2] Elements of Physiology, by Baly, p. 1317. Lond., 1839.
[3] Physiology, ii. 561, cited by Dr. Carpenter, art. Smell, in Cyclopædia of Anatomy and Physiology, pt. xxxvi. p. 703. London, June, 1849.

by savoury smells upon the appetite. It is not probable, that absorption can occur to a sufficient extent to account for the apparent satiation. The fact can only be explained by the effect upon the nervous system, which influences the appetite materially, as we see in the effect of various mental emotions. The first impact of a nauseous odour, or even the view of a disgusting object, frequently converts the keenest appetite into loathing. Yet, anciently, it was believed, that life might be sustained for a time, by simply smelling nutritious substances. Democritus is said to have lived three days on the vapour of hot bread; and Bacon refers to a man who supported an abstinence of several days by inhaling the odour of a mixture of aromatic and alliaceous herbs. Two hundred years ago these notions were entertained to a great extent; and they suggested the viaticum for travellers proceeding to the moon, according to the plan proposed by Dr. John Wilkins, Bishop of Chester.[1] "If we must needs feed upon something," he remarks, "why may not smells nourish us?" Plutarch and Pliny, and divers other ancients, tell us of a nation in India that lived only upon pleasing odours; and it is the common opinion of physicians that these do strangely both strengthen and repair the spirits." Fuller,[2] a learned cotemporary of the bishop, affords an amusing instance of litigation, arising from this supposed nourishing character of odours. A poor man being very hungry, stayed so long in a cook's shop who was dishing up the meat, that his stomach was satisfied with the smell thereof. The choleric cook demanded of him pay for his breakfast; the poor man denied having had any; and the controversy was referred to the decision of the next man that should pass by, who chanced to be the most notorious idiot in the whole city: he, on the relation of the matter, determined that the poor man's money should be put betwixt two empty dishes, and that the cook should be recompensed with the jingling of the money, as the man had been satisfied by the smell of the cook's meat.

It need scarcely be said, that if the vapour from alimentary substances be capable, in any manner, of serving the purposes of nutrition, it can only be by passing into the blood-vessels of the lungs.

3. PHYSIOLOGY OF OLFACTION.

In order that the sense of smell may be duly exercised, it is necessary that the emanation from an odorous body shall not only impinge upon the pituitary membrane, but that it shall do so with some degree of force. It must, in other words, be drawn in with the inspired air. Perrault[3] and Lower[4] found, that by making an opening into the trachea of animals, and preventing the inspired air from passing through the nasal fossæ, smell was not effected; and that dogs, which were the subjects of the experiment, readily ate food they had previously re-

[1] The Discovery of a New World, or a Discourse tending to prove, that 'tis possible there may be another Habitable World in the Moon, with a Discourse concerning the possibility of a passage thither. Lond., 1638.

[2] Holy State, London, 1640.

[3] Ess. de Phys., iii. 29.

[4] Needham, de Format. Fœtûs, p. 165; and Haller, edit. cit., v. 173.

fused. These experiments were repeated by Professor Chaussier, and with like results.[1] They explain why we use effort to draw in air loaded with an odour that is agreeable to us; and, on the contrary, arrest the respiration, or make it pass entirely through the mouth when odours are disagreeable. Still they are occasionally so diffusible and expansible, that they reach, notwithstanding, the olfactory membrane; and we are compelled to shut them off by calling in the aid of the upper extremity. The air being the ordinary medium for the conveyance of odorous molecules, we can understand why the organ of smell should form a part of the air passages.

The use of the nose is to direct the air, charged with odours, towards the upper part of the nasal fossæ. Its situation is well adapted for the reception of emanations from bodies beneath it, and its appropriate muscles allow the nostrils to be more or less expanded or contracted. These uses assigned to the nose are demonstrated by the fact, that they, whose noses are deformed—especially the flat-nosed—or whose nostrils are directed forwards, instead of downwards, have commonly the sense feebly developed. The loss of the nose, too, either by accident or disease, has been found to destroy the sense completely; and by no means the least advantage of the rhinoplastic operation is the enjoyment afforded by the improvement of this sense. M. Béclard affirms, that an artificial nose, formed of paper or other appropriate materials, is sufficient to restore it, so long as the substitute is attached.[2] It is proper to remark, however, that in a case which fell under the author's observation, although the nose had been lost by syphilis, the smell persisted; and two cases of a similar kind occurred to M. P. H. Bérard.[3]

The mode in which olfaction is effected appears to be as follows:—The inspired air, loaded with odorous particles, traverses the nasal fossæ; and, in its passage, comes in contact with the pituitary membrane, through the medium of the nasal mucus. The use of this mucus seems to be, not only to keep the organ properly lubricated, but to arrest the particles as they pass,—not by any chemical attraction, but in a mechanical manner. The olfactory nerves being distributed on the membrane, receive the impression of the molecules, and, in this manner, sensation is accomplished.

The use of the different spongy or turbinated bones would seem to be to enlarge the olfactory surface. According to some, however, they form channels to direct the air towards the openings of the sinuses. The sinuses, themselves, afford subjects for physiological discussion. By many they are considered to add to the extent of olfactory surface: by others, to furnish the nasal mucus. No hesitation would be felt in pronouncing both the spongy bones and sinuses to be useful in olfaction, were it not that the olfactory nerves or first pair have not been traced on the pituitary membrane covering the middle and inferior spongy bones, or on that lining the different sinuses;—that the sinuses are

[1] Adelon, op. cit., i. 335.
[2] Magendie, Précis Elémentaire, 2de édit., i. 136, Paris, 1825.
[3] Art. Olfaction, Dict. de Médecine, 2de édit., xxii. 9, Paris, 1840.

wanting in the infant, which, notwithstanding, appreciates odours;—that they exist only in the mammalia;—and that experiments would seem to show, that the upper part of the olfactory organ is more particularly destined for the function, and that the sinuses, which, as well as the membrane covering the middle and lower spongy bones, are supplied by filaments from the fifth pair of nerves, are not sensible to odours.

Messrs. Todd and Bowman[1]—from the fact, that on the septum narium and turbinated bones bounding the direct passage from the nostrils to the throat, the lining membrane is rendered thick and spongy by the presence of ample and capacious submucous plexuses of both arteries and veins, of which the latter are by far the larger and more tortuous—surmise, and Dr. Carpenter[2] thinks, with much probability, that the chief use of these may be to impart warmth to the air, before it enters the proper olfactive portion of the cavity; as well as to afford a copious supply of moisture, which may be exhaled by the abundant glandulæ seated in the membrane. "The remarkable complexity of the lower turbinated bones in animals with active scent, without any ascertained distribution of the olfactory nerves upon them, has"—they remark—"given countenance to the supposition, that the fifth pair may possess some olfactory endowment, and seems not to have been explained by those who rejected that idea. If considered as accessory to the perfection of the sense in the way above alluded to, this striking arrangement will be found consistent with the view, which thus limits the power of smell to the first pair of nerves."

That the upper part of the nasal fossæ is the great seat of smell is proved by the facts referred to regarding the uses of the nose. Dessault mentions the case of a young female, who had a fistula in the frontal sinuses, and who could not perceive an odorous substance, when presented at the orifice of the fistula, because there was no communication with the proper portion of the nasal fossæ, although she was capable of breathing through the opening. M. Deschamps, the younger, relates the case of a man, who had a fistula of the frontal sinus, through which ether might be injected without its odour being appreciated, provided all communication had been previously cut off between the sinus and the upper part of the nasal fossæ; but if this precaution had not been taken, the sense was more vivid, when the odours passed through the fistulous opening, than when they reached the organ by the ordinary channel. Again;—M. Richerand[3] found that highly odoriferous injections, thrown through a fistulous opening in the maxillary sinus or antrum of Highmore, produced no olfactory sensation whatever.

All these facts would seem to lead to the belief, that the upper part of the nasal fossæ, on which the first pair or olfactory nerves are distributed, is the chief seat of olfaction, and that the inferior portions of these fossæ, as well as the different sinuses communicating with them, are not primarily concerned in the function: but, doubtless, offer secondary advantages of no little importance. This conclusion, would, however, seem to admit, what is not by any means universally admitted, that the

[1] Physiological Anatomy and Physiology of Man, ii. 3.
[2] Art. Smell, Cyclop. of Anat. and Physiol., Pt. xxxvi. p. 694, Lond., June, 1849.
[3] Elémens de Physiologie, édit. 13ème par Bérard, p. 202, Bruxelles, 1837.

olfactory is the sole or chief nerve of smell. Especially difficult is it to embrace this view, and not to believe that the spongy bones and sinuses, on which the fifth pair are distributed, are agents in perfecting the sense, when we find them so largely developed in animals that possess unusual delicacy of smell, as the dog and elephant. It has already been remarked, that the ancients believed the olfactory nerves to be canals for conveying away the pituita or phlegm from the brain. Diemerbroeck, also, maintained this view.[1] At the early part of the last century, however, the olfactory was supposed to be the proper nerve of smell, and the opinion prevailed, with few dissentient voices, until within the last few years. Inspection of the origin and distribution of the nerve seems to indicate it as admirably adapted for special sensibility connected with smell. It is largely developed in animals in proportion to their acuteness of the sense, and is distributed on the very part of the pituitary membrane to which it is necessary to direct air, loaded with odorous emanations, in order that they may be appreciated. M. Magendie[2] has, however, endeavoured to show by experiment, that the sense of smell is in no wise, or little, dependent upon the olfactory nerve, but upon branches of the fifth pair. Prior to the institution of his experiments, he had observed with astonishment, that after he had removed the cerebral hemispheres, with the olfactory nerves of animals, they still preserved this sense. He had noticed, too, that it continued in lunatics, who had fallen into a state of stupor, and in whom the substance of the brain appeared, on dissection, greatly disorganized. These facts induced him to expose the olfactory nerves on living animals, and to experiment upon them; and he found, in the first place, that the nerves were insensible to puncture, pressure, and the contact of the most odorous substances. He afterwards satisfied himself, that after their division the pituitary membrane not only preserved its general sensibility, appreciated the contact of bodies, but also, strong odours, those of ammonia, acetic acid, oil of lavender, Dippel's oil, &c. On the other hand, having divided the fifth pair of nerves within the cranium, and left the olfactory nerves entire, he remarked, that the pituitary membrane had lost its general sensibility; was no longer sensible to contact of any kind; and had lost the power of appreciating odours. From these experiments, he considered himself justified in inferring, that the olfactory nerve does not preside over the general sensibility of the nose; that it has, at the most, a special sensibility as concerns odours; and that if the olfactory be the nerve of smell, it requires the influence of the fifth pair, in order that it may act. Lastly; he asks, may not the general and special sensibility be comprised in the same nerve in the sense of smell, as they are in that of taste;—in the fifth pair?

These experiments are interesting; but they by no means establish, that the fifth pair is *the* olfactory nerve. The numerous facts, already mentioned, attract us irresistibly to the first pair or *olfactory*, as they have been exclusively called. It has been already remarked, that the fifth is concerned in all the facial senses; that it conveys to them general

[1] Anatome Corporis Humani, lib. iii. cap. 8, Ultraject., 1672.
[2] Précis Elémentaire, 2de édit., i. 132.

sensibility or feeling; and that some of them are unquestionably supplied with nerves of special sensibility;—the eye with the optic; and the ear with the auditory; but that neither the one nor the other can exert its special function, without the integrity of the fifth. The olfactory nerve is probably in this category,—is the nerve of special sensibility. It is true, that in the experiments of M. Magendie the animal appeared to be affected by odorous substances, after the division of the first pair; but a source of fallacy existed here, in discriminating accurately between the general and special sensibility. Some of the substances employed were better adapted for eliciting the former than the latter;—ammonia and acetic acid, for example.

The immediate function of the sense of smell is to appreciate odours. In this it cannot be supplied by any other sense. The function is instinctive; requires no education; and is exerted as soon as the parts have attained the necessary degree of development. In many respects the sense is intimately connected with that of taste; and the impressions made upon each are frequently confounded. In the nutritive function, the smell serves as a kind of advanced guard or sentinel to the taste; and warns us of the disagreeable or agreeable nature of the aliment; but if a substance repugnant to the smell be agreeable to the taste, the smell soon loses its aversion, or at least becomes less disagreeably impressed. The smell is not, however, in man so useful as a sentinel to the taste, as it is to animals: there are many bodies,—those containing prussic acid for example,—which are extremely pleasing by the odours they exhale, and yet are noxious to man. In the animal kingdom, this sense is greatly depended upon, and is rarely a fallacious guide. It enables animals to make the proper selection of the noxious from the innocent;—the alimentary from that which is devoid of nutriment;—the agreeable from the disagreeable; and the power appears to be instinctive or dependent upon inappreciable varieties of structure in the organs concerned in olfaction.

As an intellectual sense, smell is not entitled to a higher rank than taste. Its mediate functions are very limited. It enables the chemist, mineralogist, and perfumer, to discriminate bodies from each other. We can, likewise, by it form a slight—but only a slight—idea regarding the distance and direction of bodies, owing to the greater intensity of odours near an odorous body, than at a distance from it. Under ordinary circumstances, the information of this kind derived by olfaction is inconsiderable; but in the blind; and in the savage, who is accustomed to exercise all his external senses more than the civilized, its sphere of utility and accuracy is largely augmented. Of this we shall have to speak presently. We find it, too, surprisingly developed in certain animals; in which it is considered, by the eloquent Buffon, as an eye that sees objects not only where they are, but where they have been,—as an organ of gustation, by which the animal tastes not only what it can touch and seize, but even what is remote, and cannot be attained; and he esteems it a universal organ of sensation, by which animals are most readily and most frequently impressed; by which they act and determine, and recognise whatever is in accordance with, or in

opposition to, their nature. The hound amongst quadrupeds affords us a familiar example of the extreme delicacy of this sense. For hours after the passage of game, it is capable of detecting its traces; and the bloodhound can be trained to indicate the human footsteps with unerring certainty.

Until of late years, it was almost universally believed, that many of the birds of prey possess an astonishingly acute sense of smell. Humboldt[1] relates, that in Peru, Quito, and in the province of Popayan, when they are desirous of taking the gigantic condor—*Vultur gryphus* of Linnæus—they kill a cow, or horse, and in a short time, the odour of the dead animal attracts those birds in numbers, and in places where they were scarcely known to exist. It is asserted, too, that vultures went from Asia to the field of battle at Pharsalia, a distance of several hundred miles, attracted thither by the smell of the killed![2] Pliny,[3] however, exceeds almost all his contemporaries in his assertions on this matter. He affirms, that the vulture and the raven have the sense of smell so delicate, that they can foretell the death of a man three days beforehand, and in order not to lose their prey they arrive upon the spot the night before his dissolution! The turkey-buzzard of the United States is a bird of this class, and it is surprising to see how soon they collect from immense distances after an animal has died in the forests. The observations and experiments of the ornithologist Audubon[4] would seem, however, to show that this bird possesses the sense of smell in a less degree than the carnivorous quadruped. He stuffed the skin of a deer with hay, and after the whole had become perfectly dry and hard, placed it in an open field on its back, and in the attitude of a dead animal. In the course of a few minutes a vulture was observed flying towards it, which alighted near, and began to attack it; tearing open the seams, and pulling out the hay; but finding that it could obtain nothing congenial to its taste, it took flight. It was found, too, that when animals in an advanced state of putridity were lightly covered over so as to prevent vultures from seeing them, they remained undisturbed and undiscovered, although the birds repeatedly flew over them. In some other experiments it was found, that birds of prey were attracted by well-executed representations of dead animals painted on canvass and exposed in the fields,—and in others, that young vultures, enclosed in a cage, exhibited no tokens of their perceiving food, when it could not be seen by them, however near them it was brought. These results—which were obtained, also, by Dr. Bachman in the presence of a number of scientific gentlemen of Charleston, South Carolina—are strange, inasmuch as the olfactory apparatus of the turkey-buzzard, when examined by the comparative anatomist, exhibits great development, and admirable adaptation for acuteness of smell. They are confirmed, however, by more recent experiments on the condor by Mr. Charles Darwin,[5] a distinguished natu-

[1] Rec. de Zoolog. et d'Anat. Comp., 2de livr., p. 73. Paris, 1807.
[2] Haller, edit. cit., tom. v. lib. xiv. p. 158. [3] Hist. Nat., lib. x. cap. 6, p. 230, Lugd. 1587.
[4] Ornithological Biography, p. 33, Boston, 1835; Loudon's Mag. of Nat. Hist., vii. 167.
[5] Journal of Researches into the Natural History and Geography of the countries visited during the voyage of H. M. S. Beagle round the World. Amer. edit., New York, 1846.

ralist. He tied several condors by ropes in a long row at the bottom of a wall; and having folded up a piece of meat in white paper, he walked backwards and forwards carrying it in his hand at the distance of about three yards from them; but no notice whatever was taken of it. He then threw it on the ground within one yard of an old male bird, which looked at it for a moment with attention, but regarded it no more. With a stick he pushed it closer and closer, until at last the bird touched it with its beak: the paper was then instantly torn off with fury, and at the same moment every condor in the long row began struggling, and flapping its wings. "Under the same circumstances, it would have been quite impossible to have deceived a dog."

As the organ of smell, in all animals that respire air, is situate at the entrance of the organs of respiration, it is probable that its seat, in insects, is in the mouth of the air tubes. This sense appears to guide them to the proper kinds of food, and to the execution of most of the few offices they perform during their transient existence. Occasionally, however, they are deceived by the resemblance between odours of substances very different in other qualities. Certain plants, for example, emit a cadaverous odour similar to putrid flesh, by which the flesh-fly is attracted, and led to deposit its ova in places that can furnish no food to its future progeny.

As regards the extent of the organ of smell, man is undoubtedly worse situate than most animals; and all things being, in other respects, equal, it may be fair to presume, that those, in which the olfactory membrane is most extensive, possess the sense of smell most acutely. It is curious, however, that certain animals, which have the sense of smell in the highest degree, feed on the most fetid substances. The dog, for instance, riots in putridity; and the birds of prey, to which reference has been made, but whose acuteness of smell, we have seen, has been contested, have similar enjoyment. The turkey-buzzard is so fetid and loathsome, that his captors are glad to loosen him from bondage; and it is affirmed, that if his ordinary fœtor be insufficient to produce his release, he affords an irresistible incentive, by ejecting the putrid contents of his stomach upon them![1]

One inference may, perhaps, be drawn from this *penchant* of animals with exquisite olfactories for putrid substances;—that the taste of the epicure for game, kept until it has attained the requisite *fumet*, is not so *unnatural* as might at first sight appear.

Like the senses already described, that of smell is to a certain extent under the influence of volition:—in other words, it can be exerted *actively*, and *passively*. Its active exercise—as when we smell any substance to enjoy its sweets, or test its odorous qualities—generally requires prehension, the proper direction of the head towards the object, and more or less contraction of certain muscles of the alæ nasi. Doubtless, here again, the papillæ are capable of being erected under attention, as in the senses of taste and touch. On the other hand, we can throw obstacles in the way of the reception of disagreeable odours; and, if necessary, prevent their ingress altogether, by compressing the nostrils with the upper extremity.

[1] Wilson's American Ornithology, by Geo. Ord, Philad., 1803–1814.

Lastly:—like the other senses, smell is capable of great improvement by education. The perfumer arrives, by habit, at an accurate discrimination of the nicest shades of odours; and the chemist and the apothecary employ it to aid them in distinguishing bodies from each other; and in pointing out the changes that take place in them, under the influence of heat, light, moisture, &c. In this way, it becomes a useful chemical test. The effect of education is likewise shown, by the difference between a dog kept regularly accustomed to the chase, and one that has not been trained. For the same reason, in man, the sense is more exquisite in the savage than in the civilized state. In the latter, he can have recourse to a variety of means for discriminating the properties of bodies; and hence has less occasion for acuteness of smell than in the former; whilst, again, in the latter state, numbers destroy the sense to procure pleasure. The use of snuff is one of the most common of these destructive influences.

Of the acuteness of the sense of smell in the savage we have an example on the authority of Humboldt: he affirms, that the Peruvian Indians in the middle of the night can distinguish the different races by their smell,—whether they are European, American, Indian, or negro. To the same cause must be ascribed the delicacy of olfaction generally observed in the blind. The boy Mitchell,[1] who was born blind and deaf, and whose case will have to be referred to hereafter, was able to distinguish the entrance of a stranger into the room by smell alone. A gentleman, blind from birth, from some unaccountable impression of dread or antipathy, could never endure the presence of a cat in the apartment. One day, in company, he suddenly leaped up; got upon an elevated seat; and exclaimed, that a cat was in the room, begging them to remove it. It was in vain that the company, after careful inspection, assured him he was under an illusion. He persisted in his assertion and state of agitation; when, on opening the door of a small closet, it was found that a cat had been accidentally shut up in it.

SENSE OF HEARING OR AUDITION.

Audition makes known to us the peculiar vibrations of sonorous bodies, that constitute *sounds*. It differs from the senses which have already been described, in the fact, that contact is not required between the organ of sense and the sonorous body; or between it and any emanation from the body. It is, however, a variety of touch, but produced by a medium acted upon by the vibratory body.

1. ANATOMY OF THE ORGAN OF HEARING.

The auditory apparatus is a subject of intricate study to the young anatomist; and unfortunately when he has become acquainted with the numerous minute portions to which distinct and difficult appellations have been appropriated, he has, as in many other cases, attained a tedious detail of names, without having added to his stock of physio-

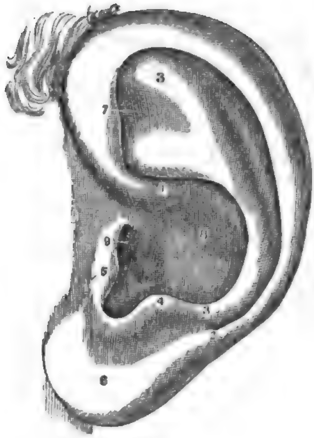
[1] Wardrop's History of James Mitchell, Lond., 1813; and Dugald Stewart's Elements of the Philosophy of the Human Mind, iii. 401, 3d edit., Lond., 1808.

logical information. Happily, it is not necessary for our purpose to go so minutely into the description of the organ of hearing. According to the plan hitherto pursued, allusion will be made to those portions only that concern the physiological inquirer.

In the ear, as well as in the eye, we have the distinction between the physical and nervous portions of the organ more clearly exhibited than in the skin, mouth, or nose. The nervous portion is situate deeply within the organ; and the parts between it and the exterior act physically—on sonorous vibrations, in the case of the ear; and on light, in that of the eye.

The organs of the senses hitherto considered are symmetrical. Those of audition are two in number, distinct but harmonious, and situate at the sides of the head, in a part of the temporal bone, generally called, from its hardness, *pars petrosa*, and by the French and German anatomists regarded as a distinct bone, under similar appellations—*Le Rocher*, and Felsenbein, ("rock-bone.") This bone is seated at the base of the skull, so that the internal parts of the auditory organ are deeply and securely lodged.

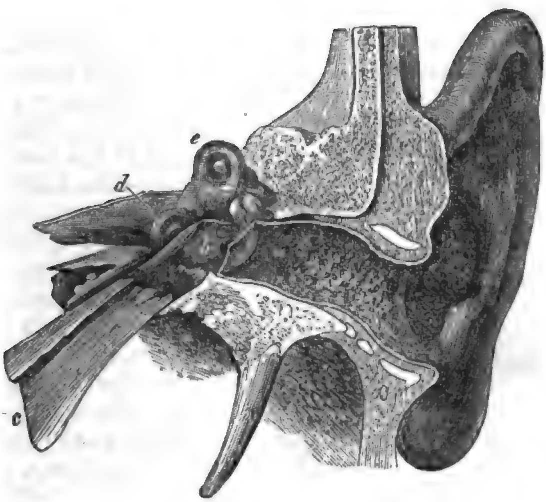
Fig. 63.



View of the Left Ear in its Natural State.

1, 2. Origin and termination of the helix. 3. Anthelix. 4. Antitragus. 5. Tragus. 6 Lobus of the external ear. 7. Points to the scapha, and is on the front and top of the pinna. 8. Concha. 9. Meatus auditorius externus.

Fig. 64.



General View of the External, Middle, and Internal Ear, as seen in a Prepared Section. (From Scarpa.)

a. The auditory canal. *b*. The tympanum or middle ear. *c*. Eustachian tube, leading to the pharynx. *d*. Cochlea; and *e*. Semicircular canals and vestibule, seen on their exterior, as brought into view by dissecting away the surrounding petrous bone. The styloid process projects below; and the inner surface of the carotid canal is seen above the Eustachian tube.

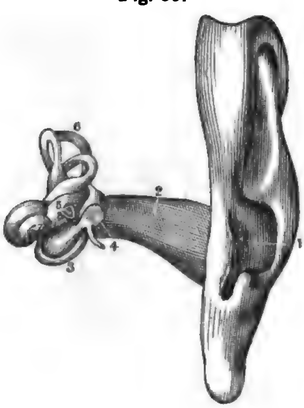
For facility of description, the ear may be divided into three portions:—1. *External ear* or that exterior to the membrana tympani; 2. *Middle ear*—the space contained between the membrana tympani and internal ear; and 3. *The internal ear* in which the auditory nerve is distributed.

1. *External Ear*. This portion of the auditory apparatus is com-

monly looked upon as an acoustic instrument, for collecting the sonorous rays or vibrations, and directing them, in a concentrated state, to the parts within. It is composed of the *pavilion*, and *meatus auditorius externus*.

The *pavilion* varies in size and position in different individuals. It is the fibro-cartilaginous, thin, expanded portion, which is an appendage, as it were, to the head. It is irregular on its anterior surface; presenting several eminences and depressions. The eminences are five in number; and have been called, by anatomists, *helix*, *anthelix*, *tragus*, *antitragus*, and *lobe*. The *helix* forms the rim of the pavilion: the *tragus* is the small nipple-like projection on the facial side of the meatus auditorius; the *antitragus* is the projection opposite to this,—forming the lower portion of the *anthelix;* and the *lobule* is the fatty, pendulous portion, to which ear-rings are attached. The depressions are three in number—the *groove of the helix* or *cavitas innominata; the fossa navicularis* or *scapha;* and the *concha*. The name of the first sufficiently indicates its situation; the second is nearer the meatus auditorius; and the third is the expanded portion, which joins the commencement of the meatus, and is bounded by the anthelix, tragus, and antitragus. The pavilion is supple and elastic; and, beneath the skin are numerous sebaceous follicles, which are distinctly perceptible, and give the skin its polish, and probably a portion of its suppleness. On the different eminences, some muscular fibres are perceptible, which it is not necessary, for our purpose, to distinguish; for in man at least they are but *vestiges*—as the French term them—to indicate the uniform plan that appears to have prevailed in the formation of vertebrated animals: if they have any office it must be unimportant. Numerous vascular and nervous ramifications are distributed on the pavilion. It is attached to the head by different ligaments, called—from their situation or attachments—*zygomato-auricular* or *anterior-auricular:—temporo-auricular* or *superior-auricular*, and *mastoido-auricular* or *posterior-auricular;* all of which terminate on the convex part of the concha. Three muscles, in animals at least, are attached to the ear to move the pavilion. These occupy the same position as the ligaments described; and have similar names. In man, they, again, are mere *vestiges;* but in many animals—as the horse—they are largely developed, and capable of moving the pavilion in various directions; and there are persons, who possess a degree of voluntary power over it.

Fig. 65.



Anterior View of the External Ear, as well as of the Meatus Auditorius, Labyrinth, &c.

1. The opening into the ear at the bottom of the concha. 2. Meatus auditorius externus or cartilaginous canal. 3. Membrana tympani stretched upon its ring. 4. Malleus. 5. Stapes. 6. Labyrinth.

The *meatus auditorius externus* extends from the inner extremity of the concha to the membrana tympani. In the adult, it

is about an inch long; narrower in its middle than extremities; longer inferiorly than superiorly, owing to the obliquity of the membrana tympani; and slightly curved upwards about its middle. The outer orifice is furnished with down or hairs—*vibrissæ*—like the orifices of certain other canals. The meatus is osseous, for the space of half an inch, and penetrates the temporal bone. More externally, it is formed of fibro-cartilage,—a prolongation of that of the concha. It is lined by an extension of the skin, which becomes gradually thinner as it proceeds inwards, and is ultimately reflected over the outer surface of the membrana tympani. Beneath this skin, numerous sebaceous glands or follicles are situate, which secrete the bitter humour, called *cerumen*. This humour occasionally becomes inspissated; obstructs the canal; prevents sonorous vibrations from reaching the membrana tympani, and is thus the cause of deafness. Softening it, by means of warm water or oil, or soap and water dropped into the meatus, and removing it by means of the syringe, restores the hearing.

The portion of the auditory apparatus arbitrarily termed the *external ear*, is a complete *cul-de-sac*, formed by a prolongation of the common integument. There is no opening communicating with the next portion—the middle ear;—the *membrana tympani*, with its dermoid envelopes, forming at once the medium of union and separation between the two. A knowledge of this fact would somewhat diminish the alarm in cases where insects or other extraneous bodies get into the meatus. The pain is excruciating, owing to the great general sensibility of this portion of the auditory apparatus; but the chief dread entertained is, that the irritating substance may pass into the head. It cannot proceed further than the membrana tympani, and even if it were able to clear this obstacle, insuperable impediments would exist to its farther progress inwardly.

Fig. 66.

A B

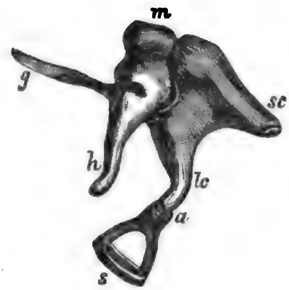
Membrana Tympani from the outer (A) and from the inner (B) sides.

1. Membrana tympani. 2. Malleus. 3. Stapes. 4. Incus.

2. The *middle ear* includes the cavity of the tympanum, the small bones contained in the cavity, the mastoid cells, Eustachian tube, &c. Like the last, it belongs to the physical portion of the ear. The *cavity of the tympanum* or *drum of the ear* has the shape of a portion of an irregular cylinder. Its name is, indeed, not inappropriate. It bears some resemblance to a drum; not only in form, but, as will be seen, in function. The outer extremity is closed, as in a drum, by the *membrana tympani*. This membrane is not situate vertically in the meatus; but obliquely downwards and inwards; so that the cavity is broader above than below. It is very thin and transparent, and consists of three layers, the outermost formed by the membrane lining the meatus auditorius externus; the innermost belonging to the membrane of the cavity of the tympanum; and the middle the membrane proper. On its inner side passes the nerve called *chorda tympani;*

and its centre affords attachment to one extremity of the chain of small bones,—to the handle of the *malleus*. The proper tissue of the membrane is dry, and it is generally esteemed to be devoid of fibres, vessels, and nerves. Sir Everard Home,[1] however, asserts, that it is muscular; that its fibres run from the circumference towards the centre, and are attached to the malleus; and that if the membrane of the human ear be completely exposed on both sides by removing the contiguous parts, the cuticular covering be washed off from its external surface, and it be placed in a clear light, the radiated direction of its fibres may be easily detected. This fibrous arrangement, Sir Everard conceives to be muscular, and on this he founds some ingenious speculations, to be hereafter noticed, regarding the appreciation of sounds. The discovery of a fibrous structure would, however, by no means prove, that the membrane is capable of contracting; or that it is formed of muscular tissue. Many ligaments, which consist of gelatin, and are, consequently, not contractile like muscles, are distinctly fibrous in their arrangement. The same may be said of tendons, whose utility, as conductors of force developed by muscle, would be materially interfered with, were they possessed of contractility. Again:—Messrs. Ruysch,[2] Sir Everard Home, and Sir Charles Bell,[3] affirm, that the membrana tympani is vascular,—Sir Everard asserting, that the vessels, in their distribution, resemble those of the iris, and are nearly half as numerous;—their general direction being from the circumference to the handle of the malleus. It is not easy to account for this discrepancy amongst practical anatomists as to the structure of the membrana tympani. A part of it is probably referable to some having directed their attention to the membrane proper; and others to the membrane with its dermoid coverings, which are highly vascular.

Fig. 67.



Ossicles of the left Ear articulated, and seen from the outside and below.

m Head of the malleus below which is the constriction, or neck. *g*. Processus gracilis, or long process, at the root of which is the short process. *h*. Manubrium, or handle. *sc*. Short crus; and *lc*, long crus of the incus. The body of this bone is seen articulating with the malleus, and its long crus, through the medium of the orbicular process, here partly concealed, *a*, with the stapes. *s*. Base of the stapes.—Magnified three diameters. (From Arnold.)

The inner extremity of the drum is partly osseous, partly membranous. Nearly opposite the centre of the membrana tympani is the *foramen ovale* seu *vestibulare*, called, also, the *fenestra ovalis* seu *vestibularis*, situate vertically, and forming a communication between the middle and internal ear. It is closed by a membrane—consisting, like the membrana tympani, of three layers—to which is attached the base of the stapes, the inner extremity of the chain of ossides that stretches across the cavity. Immediately below the foramen ovale is the bony projection called the *promontory;* and beneath this, again, a second opening, called *foramen rotundum* seu *cochleare*, and *fenes-*

[1] Philos. Transact. for 1800, P. i. p. 1, and Lectures on Comp. Anat., iii. 262, Lond., 1823.
[2] Epist. Anat. octava, p. 10. Amstel., 1724.
[3] Anat. and Physiol., edited by J. D. Godman, 5th Amer. edit., ii. 253, New York, 1827.

tra rotunda seu *cochlearis*, which forms a communication between the middle ear and the external scala of the cochlea. This foramen is closed by a membrane, similar to that of the foramen ovale; not, like it, parallel, or nearly so, to that of the tympanum,—but situate obliquely. There is no communication by a chain of bones between it and the membrana tympani.

The *small bones* or *ossicles* are four in number, so connected with each other as to form a bent lever; one extremity of which is attached to the tympanic surface of the membrana tympani,—the other to the membrane of the foramen ovale. These bones are usually termed, from their shape—beginning with the most external, and following their order—*malleus*, *incus*, *os orbiculare*, (by some not considered a distinct bone, but a process of the incus,) and *stapes*. A small muscular apparatus,—consisting of three muscles, *anterior muscle of the malleus; internal muscle* of the same bone; and *muscle of the stapes*,—is attached to the chain, which it can stretch or relax; and, of course, it produces a similar effect upon the membranes to which the chain is attached.

Bellingeri[1] thinks, that the fifth pair regulates altogether the involuntary motions of the middle ear.

At the anterior and inferior part of the cavity is the tympanic extremity of a canal, through which the drum receives the air it contains. This canal, called *Eustachian tube*, is about two inches long, and proceeds obliquely forwards and inwards from the middle ear to the lateral and superior part of the pharynx, into which it opens behind the posterior nares. It is partly osseous, partly fibro-cartilaginous and membranous; and, towards its pharyngeal extremity, expands, terminating by an oval aperture resembling a cleft. Throughout its course it is lined by a mucous membrane, which appears to be a prolongation of that of the nasal fossæ, and is capable of being more or less contracted and expanded by the muscles, which compose and move the velum palati. The cavity of the tympanum communicates, by a short and ragged canal, with numerous cells contained in the mastoid process. These cells open into each other, and vary in number, size, and arrangement in different individuals, and animals. They are called *mastoid cells*. The cavity of the tympanum is larger in animals whose sense of hearing is most acute. In man, it is about a quarter of an inch deep, and half an inch broad, and is lined by a prolongation of the same membrane as that which lines the Eustachian tube. This membrane, as we have seen, covers the membrana tympani, and the membranes of the foramen ovale, and foramen rotundum. It likewise lines the mastoid cells, and is reflected over the small bones.

The middle ear does not exist in every animal endowed with hearing. It does not begin to appear lower in the scale than reptiles; and is by no means equally complex in all. Frequently, the chain of bones is entirely wanting; and at other times we find one bone only.

3. The *internal ear* or *labyrinth* is the most important part of the apparatus. It consists of several irregular cavities in the pars petrosa of the temporal bone, in which the nerve of audition is distributed. It is,

[1] Edinb. Medical and Surgical Journal, July, 1834, p. 128.

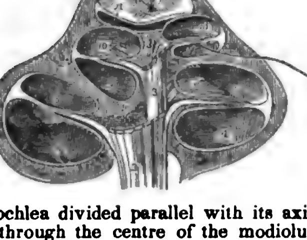
Fig. 68.

Labyrinth separated from the solid bone in which it lies embedded.

V. Vestibule. X, Y, Z. Semicircular canals. K. Cochlea. O. Fenestra ovalis. R. Fenestra rotunda.

consequently, here that the physical part of audition terminates, and the nervous begins. The labyrinth comprises the *vestibule*, *semicircular canals*, and *cochlea*. The *vestibule*—as its name imports—is the hall, that communicates with all the other cavities of the labyrinth. It would appear to be the most essential part of the organ, as it often exists alone. At its inner surface are numerous small foramina, which communicate with the bottom of the meatus auditorius internus, and through which the filaments of the auditory nerve reach the labyrinth. Externally, it communicates with the cavity of the tympanum by the foramen ovale. Posteriorly, it opens into the semicircular canals by five foramina; and anteriorly, by a single foramen, into the internal scala of the cochlea. There is, also, posteriorly and inferiorly, near the common orifice of the two vertical semicircular canals, the opening of a small, bony duct, which terminates internally at the posterior surface of the petrous portion of the temporal bone. This duct is called *aquæductus* seu *diverticulum vestibuli*. The *semicircular canals* are three in number, and occupy the hinder part of the labyrinth. They are called *superior vertical*, *posterior vertical*, and *horizontal*. They are cylindrical cavities, curved semicircularly, and are more expanded at their vestibular origin, which has been, therefore, called *ampulla*. They are constituted of a plate of bone, situate in the spongy tissue of the pars petrosa, and all of them communicate with the vestibule. The *cochlea* is the most anterior portion of the labyrinth. It is so called in consequence of its resemblance—in man and mammalia—to a snail's shell; hence, also, its French and German names, *limaçon*, and Schnecke. It is the most intricate part of the organ of hearing, and does not admit of easy description. It is a conoidal canal, spirally convoluted, making two turns upon itself, and resting on a bony nucleus or pillar, called *modiolus*. The base of the nucleus is concave; corresponds to the bottom of the meatus auditorius internus, and is pierced by small foramina, through which the filaments of the au-

Fig. 69.

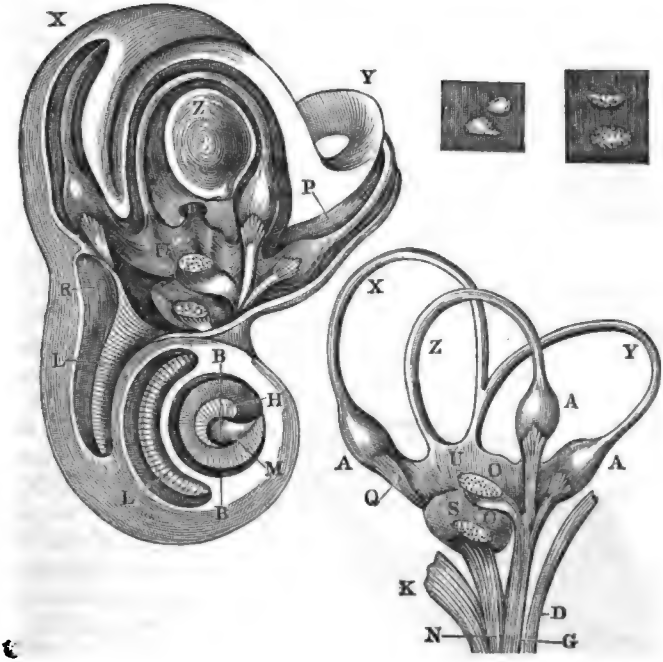


Cochlea divided parallel with its axis, through the centre of the modiolus. (Breschet.)

1. Modiolus. 2. Infundibulum in which the modiolus terminates. 3, 3. Cochlear nerve, sending its filaments through centre of modiolus. 4, 4. Scala tympani of first turn of cochlea. 5, 5. Scala vestibuli of first turn. 6. Section of lamina spiralis, its zonula ossea; one of the filaments of the cochlear nerve is seen passing between the two layers of the lamina spiralis to be distributed upon the membrane which invests the lamina. 7. Membranous portion of the lamina spiralis. 8. Loops formed by filaments of cochlear nerve. 9, 9. Scala tympani of second turn of cochlea. 10, 10. Scala vestibuli of second turn; the septum between the two is the lamina spiralis. 11. Scala tympani of remaining half turn. 12. Remaining half turn of scala vestibuli; the dome placed over this half turn is the cupola. 13. Lamina of bone which forms the floor of the scala vestibuli curving spirally around to constitute the infundibulum (2). 14. The helicotrema through which a bristle is passed; its lower extremity issues from the scala tympani of middle turn of cochlea.

ditory nerve reach the cochlea. The spiral canal is divided, in its whole length, by a partition, half osseous and half membranous, called *lamina spiralis;* so that two distinct tubes are thus formed. These are the *scalæ of the cochlea.* At the apex of the cochlea they run into each other, by an opening termed by M. Breschet *helicotrema;* and at the base, one turns into the vestibule, and is hence called *superior* or *vestibular* or *internal scala;* the other communicates with the cavity of the tympanum by the foramen rotundum, and is called *inferior, tympanic*, or *external scala.* At this scala, near the foramen rotundum, a bony canal begins, which proceeds towards the posterior surface of the pars petrosa, on which it opens. It is *aquæductus* seu *diverticulum cochleæ.* The cochlea does not exist in all animals that hear. It is not, therefore, of essential importance. It varies, too, greatly, in complication, in different animals. In birds, whose hearing is extremely delicate, it merely consists of a short, hollow, bony process, divided into two scalæ but without any spiral arrangement. In reptiles, it is still more imperfect; and in many species can scarcely be said to exist. In fishes there is no trace of it.

Fig. 70.



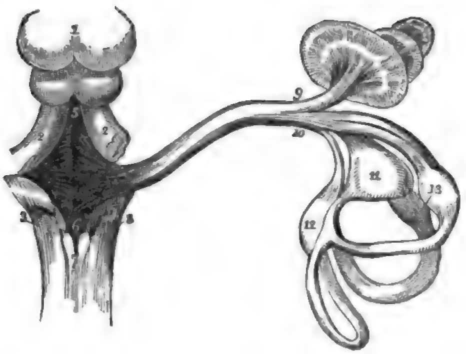
Osseous Labyrinth laid open to show especially the Membranous Labyrinth.

X, Y, Z. Semicircular canals. A, A, A. Ampullæ. P. Perilymph between the osseous and membranous labyrinth. U. Utricle. S. Sacculus. O, O. Cretaceous bodies. G, N. Auditory nerve. K. Branch going to the cochlea. L. Lamina spiralis. M. Apex of modiolus. D. Portio dura.

The different cavities of the internal ear are lined by an extremely delicate membrane. In many animals this membrane exists alone,

without any bony parietes. It exhales at its inner surface a limpid fluid, called *liquor* or *lymph* of Cotugno or Cotunnius, *perilymph* of Breschet, which, under special circumstances, can reflow into the aquæductus vestibuli and aquæductus cochleæ. This fluid is contained in all the cavities of the internal ear. Within that of the osseous labyrinth are contained membranes having nearly the shape of the vestibule and semicircular canals, but not extending into the cochlea. These membranes, which compose what has been called the *membranous labyrinth*, form a continuous but close sac, containing a fluid, *endolymph*,—termed by M. De Blainville *vitrine auditive*, from its supposed analogy to the vitreous humour of the eye. It is similar in appearance to the perilymph, which surrounds it on the outer side, and intervenes between it and the sides of the osseous labyrinth so as to prevent any contact. The form of the membranous vestibule requires special notice, as it is not an exact imitation of the osseous cavity, being composed of two distinct sacs which open into each other; one of these is termed *utricle*, *sinus* seu *alveus utriculosus*, *sacculus vestibuli*, and *median sinus;* the other, *sacculus*. Each sac contains in its interior a small mass of white calcareous matter resembling powdered chalk, which seems to be suspended in the fluid of the sacs, by means of nervous filaments proceeding from the auditory nerves, G, N, Fig. 70. From the universal presence of these substances in the labyrinth of all the mammalia, and from their much greater size and hardness in aquatic animals, it is presumable, that they perform some office of importance in audition. They are termed by M. Breschet, *otolithes*

Fig. 71.



Auditory Nerve.

1. Corpora quadrigemina. 2, 2. Processus è cerebello ad testes. 3, 3. Corpora restiformia. 4. Fourth ventricle. 5. Iter a tertio ad quartum ventriculum. 6. Calamus scriptorius. 7. Posterior median columns of spinal cord forming by their divergence the point of the calamus, also called *ventricle of Arantius*. 8. Lines of origin of 4th ventricle, and of auditory nerve. 9. Anterior branch distributed to cochlea. 10. Posterior or vestibular branch. 11. Utriculus communis concealing sacculus proprius from view. 12. Ampulla of oblique semicircular canal. 13. Ampullæ of perpendicular and horizontal semicircular canals.

Fig. 72.

Ampulla of the External Semicircular Membranous Canal, showing the mode of termination of its Nerve.

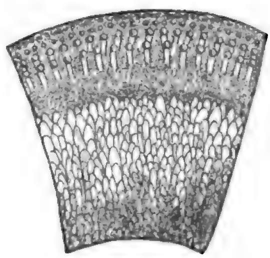
and *otoconies*, according as they are of a hard or a soft consistence. The small square figures (Fig. 70), represent their size and appearance in the dog and the hare.

Fig. 73.

Auditory Nerve taken out of the Cochlea.

1, 1, 1. Trunk of the nerve. 2, 2. Its filaments in the zona ossea of the lamina spiralis. 3, 3. Its anastomoses in the zona vesicularis.

Fig. 74.



Papillæ of the Auditory Nerve, on a segment of the spiral lamina of the cochlea of a young Mouse.

The lower portion is the osseous, and the higher the membranous part of the lamina.—Magnified 300 times.

It is in the cavities of the internal ear, and on the different parts of the membranous labyrinth, that the *auditory* or *acoustic nerve* is distributed. This nerve is the *portio mollis* of the seventh pair, of most anatomists. It arises, like other nerves of the senses, from the medulla oblongata; and near the anterior paries of the fourth ventricle. Thence it passes obliquely outwards, forwards, and upwards, and enters the meatus auditorius internus, the foramen of which is situate on the posterior surface of the pars petrosa. The base of this meatus corresponds to the inner surface of the vestibule, and to the base of the cochlea. Through the first foramen, near the base of the meatus, the portio dura of the seventh pair or facial nerve passes to gain the aqueduct of Fallopius; along which it proceeds, giving off filaments to different parts of the middle ear, and ultimately issuing by the stylo-mastoid foramen to be lost on the muscles of the face. Below the part of the meatus, where the facial nerve emerges, are several other foramina, through which filaments of the auditory nerve attain the labyrinth. These are distributed to the vestibule, semicircular canals, and cochlea; and terminate, by very delicate ramifications, in the tissue and at the surface of the membrane that lines the labyrinth. The precise mode in which the ramifications terminate has been a matter of dispute: some affirming, that they end in papillæ, as in the marginal figure from Treviranus (Fig. 74); others, that the fibres return by loops. The arrangement is probably analogous to that which prevails in the retina.[1]

Such is the apparatus concerned in the function of audition. Before proceeding to the physiology of these different parts, and the assistance

[1] Carpenter's Human Physiology, § 352, Lond., 1842.

afforded to the mind by this sense, it is necessary to enter into a brief physical disquisition on sound.

2. SOUND.

If a body, by percussion or otherwise, be thrown into vibration, every vibration excites a corresponding wave in the air; and these oscillations are propagated in all directions, until gradually lost in distance; but if they strike on the organ of hearing with the necessary force, a sensation is produced, which is called *sound* or *noise*. The term, however, is frequently used to signify, not only the sensation, but the affection of the air, or of the sonorous body by which the sensation is effected.

That bodies move or oscillate when they produce sound admits of easy detection. We can see it in drums, bells, musical strings, &c., whose vibrations are extensive; and can arrest them, and with them the sound, by putting the hand upon the body, or muffling it. Whenever a sonorous body is struck, a change in the relative position of its molecules is produced. These, by virtue of their elasticity, tend to return to their former place. This is done by a series of oscillations, which are, at first, more extensive; but become gradually less, until they finally cease. The rapidity of these oscillations is greater in bodies that are hard and elastic; and hence it has been concluded, that these two qualities render a body sonorous. It is not, however, a matter of facility to say, what is the precise cause of the difference of sound in analogous bodies. It must be dependent upon intimate composition, but of what nature is not intelligible to us. There are but one or two individuals in Great Britain, who have been celebrated for the fabrication of the larger order of bells for churches, colleges, &c., and in certain countries the art is comparatively unknown. Resonance is entirely owing to the intimate composition of the body, and is beautifully and singularly exhibited in the *Chinese gong*, the sound of which continues to rise for some time after a succession of rapid and forcible blows has been inflicted.

But, in order that sonorous oscillations may affect the organ of sense, an intermediate body is necessary to repeat and transmit them. This body is called the *vehicle of sound*, and it is usually air. M. De Lamarck supposes the existence, in the atmosphere, of a vibrative fluid of great subtilty, which pervades the globe as well as the bodies on its surface; and Geoffroy St. Hilaire affirms, that sound "is a matter resulting from the combination of the external air, with the polarized air of the sonorous body!"—but these are topics that belong to works on higher physics.

Air, by virtue of its elasticity, is admirably adapted as a vehicle for sound; and the loudness of the sound conveyed by it is greatly dependent upon its density. If we put a bell under the receiver of an air-pump, and exhaust the air, the sound becomes gradually more and more faint, and when the air is exhausted is not heard at all. For the same reason a pistol fired on the top of the Himāla Mountains gives a much feebler report than in the valleys beneath.

Sympathetic sounds afford additional evidences of the carrying power

of air. Every sonorous, elastic body can be thrown into oscillations, if the air surrounding it be made to tremble. Thus, if we sound a note near a piano-forte, whose dampers are raised so as to admit of free vibration, the string, that is in unison with the tone produced, will vibrate by *reciprocation;* and a wine-glass or goblet may, according to Dr. Arnott, be made to tremble, and even to fall from a table, by sounding on a violoncello near it the note that accords with its own. The strata of air, in proximity with the sonorous body, receive the first impulses; and from these they are successively propagated to others; much in the same manner as the undulations extend from the place in which a stone is cast on a surface of smooth water; except that the aerial undulations extend in every direction, whilst the aqueous proceed only horizontally. In this propagation from stratum to stratum a portion of the sound is necessarily lost; so that the loudest sound is heard only within certain limits; and, in all cases, its intensity is inversely as the square of the distance from the sonorous body.

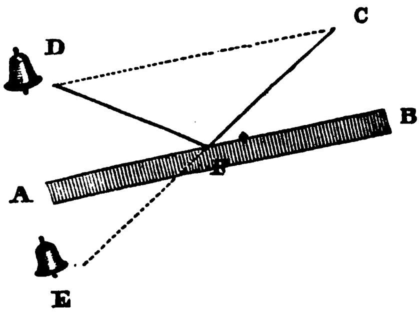
By causing the sonorous undulations to proceed entirely in one direction, and preventing their escape in every other, sound may be rendered audible at a much greater distance. M. Biot found, that when he spoke in a whisper at one extremity of a cylinder upwards of one thousand yards long, he was distinctly heard at the other. In many large manufactories the knowledge of this fact is turned to good account. By having numerous tubes communicating with the different rooms of the establishment, and terminating in the office of the principal, he is enabled to have his directions readily conveyed, and to receive information without the slightest inconvenience.

The velocity with which sound proceeds admits of easy calculation. Light passes with such rapidity, that it may be regarded as proceeding instantaneously from objects on the earth to the eye. The velocity of sound is incomparably less. We see the flash of a gun at a distance; and, some time afterwards, hear the report. Considering the light then to have reached the eye instantaneously, if we know the distance of the gun, and note the time that elapsed between the appearance of the flash and the report, we can calculate accurately the rapidity of sound. This is found to be about eleven hundred and forty-two feet in a second. We can, in this manner, estimate the distance of a thunder-cloud, by noting the time of the flash, and the interval that elapses before hearing the clap. If it be thirty-seconds, the cloud is at a distance of thirty times eleven hundred and forty-two feet, or six miles and a half. The velocity is the same for all kinds of sounds. M. Biot found, on playing a flute at the end of the tube, above referred to, that the tones arrived at the ear placed at the other extremity in due succession; so that their velocity must have been uniform.

When aerial oscillations meet with a resisting body of a regular surface, as A B, Fig. 75, they are reflected at an angle equal to the angle of incidence: consequently, an ear, placed in the course of the reflected waves as at C, will refer the sound to a distance as far behind the point of reflection, and in the direction of the reflected ray, as the sonorous body is from the point of reflection. It will seem to be at E. The ear at C will, however, receive the direct oscillations from the bell D, as

well as those that proceed along the lines D F and F C; or in other words, it will hear both the sound and its echo; and, if the surfaces on which the sonorous undulations impinge be favourably disposed, the echoes may be very numerous. The utility of the *ear trumpet*, and *speaking trumpet*, is to be explained by this law of the reflection of the aerial undulations; and some physiologists are of opinion, that the external ear is inservient to audition on similar principles. The *ear trumpet* is a tube, narrow at one extremity, so as to enter the concha; and expanded at the other like a trumpet. It is also curved, so that it may be easily directed to objects. All the sonorous rays, that enter the expanded extremity, are brought after various reflections to a focus in the auricular end; and the intensity of the sound is, in this way, so much augmented, that a person who, without it, is entirely deaf to common conversation, may enjoy it. A sheet of paper, folded like a cone, the apex of which is placed in the concha, and, to a less extent, the hand held concavely behind the ear, serve a like purpose.

Fig. 75.



Reflection of Sound.

Air is not the only, nor the most perfect, vehicle of sound. The personal experiments of divers show, that it can be conveyed through water. The blows of workmen around a diving bell are distinctly heard above; and fish have manifestly an acute sense of hearing, although this was at one time denied. An experiment, made by the Abbé Nollet, and repeated by Dr. Franklin, proves, that water transmits a much stronger vibration than air. When two stones were struck together under water, a shock was given to the ear, which was almost insupportable. The latter philosopher found by experiment, that sound, after travelling above a mile through water, loses but little of its intensity. According to Chladni, its rate of progression in water is about 4900 feet in a second, or between four and five times as great as in air. Solids, too, are much better conductors of sound than air. If we scratch one end of a wooden rod, the sound is distinctly heard by the ear applied to the other; although it may be inaudible through the air. Savage tribes are in the habit of discovering the advance of enemies, or of their prey, by applying the ear to the ground; and watchmen, in some towns, instead of springing a rattle, and alarming offenders, strike the pavement with a staff, the sound of which is heard by their fellow-watchmen at a considerable distance. It is a common practice to ascertain, whether a kettle boils, by putting one end of a poker on the lid, and the other to the ear. The difference between simmering and boiling is in this way detected. A knowledge of the ready communication of sound through solids, has given rise to a valu-

able suggestion for the discrimination of diseases of the chest, and of various healthy and morbid conditions. By putting the ear to the chest we can hear the rush of air along the bronchial tubes, the pulsations of the heart, &c., and can discover any aberration in the execution of their functions. This is what was called by the late distinguished Laënnec, of Paris—the proposer of the method—*immediate auscultation*. The direct application of the ear to the chest is, however, frequently inadmissible. In these cases he used a hollow cylinder called a *stethoscope*, one end of which he applied to the chest—the other to the ear. This plan he termed *mediate auscultation*. The suggestion has led to valuable improvements in diagnosis.

MM. Hassenfratz and Biot have made some accurate experiments on the comparative rapidity of the progress of sound through air and solid bodies. The latter found, in the aqueducts of Paris, that a blow, struck upon a pipe nine hundred and fifty-one metres, or about ten hundred and forty yards, in length, was heard two seconds and a half sooner through the sides of the pipe than through the air within; but the sound did not extend so far. Ice conveys sound even better than water; for if a cannon be fired from a distant post—a frozen river intervening—each flash is followed by two distinct reports, the first conveyed by the ice,—the second by the air.

It has been already stated, that the vibrations of air, caused by a sonorous body, are capable of exciting corresponding or *sympathetic vibrations* in solid bodies within their sphere of action. It was an old observation, that such vibrations are excited only in bodies that are in unison with the sonorous body; in other words, in those that are capable of producing the same tone. Unison, however, is not necessary. When a sound is produced in air, every body receives a vibration, which is a repetition of the one that occasioned the sound. This M. Savart proved by using small membranes on which he placed fine sand. They were agitated; and the sand assumed various regular arrangements, whenever a sound was produced in their vicinity. In other words, the membrane was thrown into vibration, not as a whole, unless its fundamental note was in unison with the one sounded; but in distinct segments, every one of which reciprocated the sound. This law of physics is important in its physiological relations. The apparatus of audition consists of several membranous structures, which are thrown into oscillation, whenever the ear receives the impressions of sound.

The vibrations, which produce sound, differ much as regards their extent and rapidity; and on these differences two of the qualities of sound—*strength* and *tone*—are dependent. *Strength* or *intensity* depends on the extent of the vibrations of a sonorous body. This is seen in a musical string, the sound of which becomes weaker as the extent of the oscillations diminishes. The *tone*, on the other hand, is dependent on the rapidity of the oscillations;—on their number in a given time. The tone, produced by a string or other sonorous body that vibrates quickly, is termed *acute* or *sharp*, when compared with that of one which vibrates more slowly. The latter is called *grave*, when compared with the former. The gravest sound that the ear can appreciate is considered to result from thirty-two vibrations per second; the most

acute, from eight thousand one hundred and ninety-two vibrations, according to some;—twelve thousand, according to others. Some well-devised experiments, however, made by M. Savart, largely extend these limits, and appear to indicate that they cannot be esteemed rigidly fixed. In his experiments, the ear distinctly appreciated fourteen or sixteen vibrations, or seven or eight impulses per second; and the acutest note that was audible proceeded from upwards of forty thousand vibrations, or more than twenty thousand impulses per second. Recently, M. Despretz[1] has determined, that classifiable sounds are comprised between the limits of 32 simple vibrations for the lowest tone, and 73,000 for the highest.

The duration of the impression of a sonorous vibration on the ear has been estimated at about the sixteenth part of a second; but it is difficult to determine it exactly.

If a sonorous body be struck, and the vibrations excited be all performed in equal times, a simple and uniform sensation is produced on the auditory nerve, and one *musical tone* is heard. But if the vibrations be various and irregular, they fall scatteringly on the organ of hearing, and excite a harsh impression, as if various sounds were heard together. In other words a *noise* or *discord* is produced. If two notes, sounded together, afford pleasure, they produce *harmony* or *concord*. This arises from the agreement of the vibrations, so that some of them strike upon the ear at the same time. If, for example, the vibrations of one sonorous body take place in double the time of another, the second vibration of the latter will strike upon the ear at the same instant as the first vibration of the former. This is the concord or harmony of an *octave*. Between a note and its octave, there are six intermediate notes, constituting the *diatonic scale* or *gamut*. If the vibrations of two strings are as two to three, the second vibration of the former will correspond with the third vibration of the latter, producing the harmony called *a fifth*. There are other tones, which, although they cannot be struck together without producing discord, if produced in succession, give the pleasure called *melody*. Melody is, in truth, nothing more than the effect produced on the brain by pleasing musical tones sounded in succession.

There is another quality of sound which the French call *timbre*. By some of the translators of the works of the French physiologists and physicists this word has been rendered *note*. It is essentially different from note or tone; and is peculiar. By English philosophers it is termed *quality* of sound. It is this *quality* that enables us to recognise various instruments, when giving forth the same note or tone; and to distinguish the voices of individuals from each other. Its cause is not evident, but is conceived to depend upon the nature of the sonorous body, if it be a surface,—and at the same time on its shape, if a tube. M. Biot conjectures, that it is owing to the series of harmonic sounds that form part of every appreciable sound. When any sonorous body is made to vibrate, a distinct sound is heard, which is the *fundamental;* but, if attention be paid, others are heard at the same time. These are called *harmonics;* and it is not improbable that *timbre* or

[1] Comptes Rendus, xx. 1214, cited by Longet, Traité de Physiologie, ii. 136, Paris, 1850.

quality may be dependent as well upon the nature of the sonorous body, as upon the greater or less number of harmonics, that accompany the fundamental sound.[1]

3. PHYSIOLOGY OF AUDITION.

In tracing the progress of sonorous vibrations to the internal ear, we shall follow the order of parts described in the anatomical sketch of the auditory apparatus;—commencing with the *external ear*. The meatus auditorius externus being always open, sonorous vibrations can readily reach the membrana tympani. Some of these pass directly to the membrane without experiencing reflection, and communicate their oscillations to it. The *pavilion* has been regarded, by most physiologists, as a kind of ear-trumpet, for collecting aerial undulations, and directing them, after various reflections, to the bottom of the auditory canal. In the horse, and in those animals which have the power of pricking the ears, or of moving them in various directions, this is doubtless the case; but in man we cannot expect any great effect of the kind, if we regard its arrangement, and the incapability of moving it from its fixed direction, which is nearly parallel to the head. Boerhaave,[2] indeed, pretended to have proved by calculation, that every sonorous ray, which falls upon the pavilion, is ultimately directed towards the meatus auditorius externus. Simple inspection of the pavilion shows that this cannot be universally true. Some part of the anthelix is, in almost every individual, more prominent than the helix; and it is therefore impossible for the undulations, that fall upon the posterior surface of the former, to be reflected towards the concha. M. Itard,[3] a distinguished physiologist and aurist of Paris, asserts, that he has never seen the loss of the pavilion affect the hearing; and many animals, whose sense of hearing is acute,—the mole and birds, for example,—are devoid of it. Hence he concludes, that it is, perhaps, rather injurious than favourable to audition; and is more inservient to the expression than to the hearing of the animal.

M. Itard's view is doubtless too exclusive. The pavilion may have but little agency as an ear-trumpet, but it must have some. The concha, being the expanded extremity of the meatus auditorius, must receive more sonorous vibrations than could be admitted by the meatus itself. These are reflected towards the membrana tympani, and reach it in a state of concentration—but, to no great amount, it is true. In this way, and perhaps in that suggested by M. Savart,[4] the pavilion is useful in audition. That gentleman is of opinion, that the whole of the external ear, the elasticity of which he considers to be capable of slight modification by the action of its proper muscles, is an apparatus for *repeating* sonorous vibrations, and transmitting or conducting them along its own parietes to the membrane of the tympanum. According to this view, the different inequalities of surface of the pavilion admit

[1] On sonorous undulations in general, see Müller's Elements of Physiology, by Baly, Pt. v. p. 1215, Lond., 1839.
[2] Prælect., tom. iv. p. 317.
[3] Traité des Maladies de l'Oreille et de l'Audition, i. 131, Paris, 1821.
[4] Annales de Chimie, xxvi. 5; and Journal de Physiologie, iv. 183, and v. 367.

of explanation. When the membrane is stretched in a direction parallel to a sonorous surface, the oscillations, impressed upon it, are most marked; and, accordingly, as sounds impinge upon the pavilion from various quarters, the inequalities of surface always admit of some being disposed in the most favourable way for the reception of vibrations. It is true that the pavilion is not essential to audition; the hearing not suffering by its removal for more than a few days; so that its physiological influence is much more limited than might be conceived. It probably contributes to a knowledge of the direction of sounds, and is certainly calculated to protect the membrana tympani.

The *meatus auditorius externus* conducts the sonorous vibrations directly, and by reflection, as well as by its parietes, to the membrana tympani. It is probable, too, that it is useful in protecting the membrane from the direct action of air and extraneous bodies. This is, perhaps, the cause of its tortuous character. If too much so, hearing becomes impaired,—the sonorous oscillations not being properly directed towards the membrane. Baron Larrey has published cases of deafness produced in this manner, which were removed by wearing an artificial concha and meatus of the natural curvature made of gum elastic. The down or hairs, at the entrance of the meatus, have been regarded as protecting agents against the intrusion of extraneous bodies; whilst the cerumen has been looked upon as a fit material for entrapping insects in the slough formed by it, or for destroying them by its poisonous influence. It is probable, however, that the most important function of the cerumen is to keep the lining membrane of the meatus in a physical condition adapted for the proper fulfilment of its functions.

Middle Ear.—In the mode described, the vibrations of a sonorous body attain the membrana tympani. An experiment by M. Savart would seem to show, that the membrane is thrown into vibrations chiefly by the air contained in the meatus. He made a small truncated cone of pasteboard, and closed the narrow extremity by a tense membrane, nearly as the membrana tympani closes the inner extremity of the meatus auditorius; and he found, that when sounds were produced near the parietes of the cone, the membrane vibrated but little; whilst if they were occasioned opposite the base of the cone, so that they could be transmitted to the membrane by the air within the canal, the vibrations were distinct, even at a distance of thirty yards and upwards.

The membrane of the tympanum, then, receives and repeats the sonorous vibrations. It has, however, been supposed to be possessed of other functions. M. Dumas[1] conceived it to be composed of numerous cords, each corresponding to some particular tone. But of this arrangement we have no evidence from observation or analogy. By others, it has been supposed, and with probability, that the membrane is capable of being rendered tense, or the contrary, by the bent lever, formed by the chain of ossicles. They have farther presumed, that this tension or relaxation is adapted to the sounds, which the membrane has to transmit. The ancients believed, that the adaptation was

[1] Principes de Physiologie, 2de édit., Paris, 1806.

produced by the stretching of the membrane, so as to put it in unison with the sound produced. Independently, however, of the experiments of M. Savart, which show, that unison is not necessary for the production of vibrations, the fact, that we are capable of distinguishing several sounds at the same time, would seem to negative the supposition. Nor can we easily conceive, that the membrane could admit of as many distinct vibrations as the ear is capable of accurately appreciating tones, amounting to about eight octaves. Bichat thought, that the degree of tension of the membrane corresponded with the intensity of sounds; and that by it the sonorous vibrations attained the internal ear in a degree sufficiently strong to excite the appropriate impression, but not so strong as to cause pain,—the membrane becoming more tense for a feeble sound, and relaxed for one too strong. In support of this view, Bichat cites the case of several persons, who could not hear ordinary sounds, until the ear had been impressed by louder, which, according to him, roused the membrane to tension. M. Savart, on the other hand, from the fact that every membrane vibrates with more difficulty, and less extensively, according to its tension, conjectures that the membrane is relaxed in the case of very feeble or agreeable sounds, and is rendered tense to transmit the too powerful or disagreeable.

Again, it has been conceived that the tension varies with the tone of the sound,—being augmented according to some physiologists, in acute, according to others, in grave sounds. Sir Everard Home,[1] it has been remarked, esteems the membrane to be muscular: and he affirms, that it is chiefly by means of this muscle, that accurate perceptions of sound are made by the internal organ; and that the membrane can alter its degree of tension. It has been before observed, that the muscles, attached to the small bones, are capable of varying this tension; that the internal muscle of the malleus or tensor tympani, for example, by its contraction, renders it more tense. Sir Everard admits, "that the membrana tympani is relaxed by the muscle of the malleus, but not for the purpose alleged in the commonly received theory. It is stretched in order to bring the radiated muscle of the membrane itself into a state capable of acting, and of giving those different degrees of tension to the membrane, which empower it to correspond with the variety of external tremors: when the membrane is relaxed, the radiated muscle cannot act with any effect, and external tremors make less accurate impressions." The reader is referred to the remarks already made on the views of Sir Everard in their anatomical relations. His speculations do not, however, end here. He employs the discovery to account for the difference between a "musical ear," as it is usually termed, and one which is incapable of discriminating, or feeling pleasure from, the succession of musical tones,—with what success we shall inquire presently. The truth is, that none of the conjectures, which have been proposed regarding the precise effects of tension or relaxation of this membrane, can be looked upon in any other light than as ingenious speculations, based, generally, upon the fact, that the membrane seems certainly capable of being varied in its tension by the

[1] Lect. on Comp. Anat., iii. 265.

movements of the chain of bones, but leading to no certain knowledge of the precise effect on audition of such tension or relaxation.[1] In fact, although the integrity of the membrane is necessary for perfect hearing, its perforation or destruction does not induce deafness. We have numerous cases of perforation from accident and otherwise, related by Messrs. Valsalva,[2] Willis,[3] Riolan,[4] Flourens, and others, in which the hearing continued; and, in certain cases of deafness, the membrane is actually punctured for the purpose of restoring the hearing.

The communication of sonorous oscillations from the membrana tympani across the cavity of the tympanum to the internal ear is effected in three ways: 1st, by the air contained in the cavity of the tympanum; 2dly, by the chain of bones to the membrane of the foramen ovale; and 3dly, by the parietes of the tympanum. So that, if the membrana tympani should be punctured or destroyed, the aerial undulations, caused by a sonorous body, which enter the meatus auditorius, may extend into the cavity of the tympanum, and excite corresponding oscillations in the membranes of the foramen ovale, and foramen rotundum. The chorda tympani—composed, perhaps, wholly of a branch of the fifth pair, and distributed on the interior of the membrana tympani—probably conveys no acoustic impression to the brain. To it is owing the excessive pain, which is caused by the contact of an extraneous body with the membrane; and that occasioned by a loud noise, or by compressing the air forcibly in the meatus by passing the finger suddenly and strongly into the concha.

The uses of the *mastoid cells*, which communicate with the middle ear, are not known. It would seem, that the strength of audition is in a ratio with their extent. In no animals are they more ample than in birds, which are possessed of great delicacy of hearing. This effect may be induced either by their enlarging the cavity of the tympanum, and allowing the sonorous oscillations to come in contact with a larger surface; or by the plates which compose them being thrown into vibration. It has been conceived, too, that they may serve as a diverticulum for the air in the middle ear, when it is subjected by the membrana tympani to unusual compression.

Sir Charles Bell,[5] with more warmth than is judicious or courteous, combats the idea of the *foramen rotundum* receiving the undulations of air. The oblique position of the membrane of the foramen with regard to the membrana tympani satisfactorily, he thinks, opposes this doctrine. The function which, with M. Savart, he assigns to it—if not accurately, at least ingeniously—is the following. As the membrane of the foramen ovale receives the vibrations from the chain of ossicles, these vibrations circulate through the intricate windings of the labyrinth, and are again transmitted to the air in the tympanum by the foramen rotundum. The different cavities of the labyrinth being filled with incompressible fluid, no such circulation, he insists, would occur, provided the parts were entirely osseous. As it is, the mem-

[1] For the fancied uses of this membrane, see Haller, Element. Physiol., v. 198, Lausan., 1769.
[2] Op. Anat. de Aure Humanâ, &c., Ed. J. A. Morgagni, Venet., 1740.
[3] Oper. Omn. Venet., 1720.
[4] Enchirid. Anat., l. iv. c. 4, Lugd. Bat., 1649.
[5] Op. citat., i. 269.

brane of the foramen rotundum gives way, "and this leads the course of the undulations of the fluid in the labyrinth in a certain unchangeable direction." The explanation of Sir C. Bell is not as convincing to us as it seems to be to himself. The membrane of the foramen rotundum does not appear to be required for the undulation in the cavities of the labyrinth, which he describes; as the liquor of Cotunnius can readily reflow into the aqueducts of the vestibule and cochlea. The principal use of these canals would seem, indeed, to be, to form *diverticula* for the liquor when it receives the aerial impulses. Sir C. Bell cites the case—often quoted from Riolan—of an individual who was deaf from birth, and was restored to hearing by accidentally rupturing the membrana tympani, and breaking the ossicles with an ear-pick:—"*disrupit tympanum, fregitque ossicula, et audivit.*" In these and other cases, in which the membrana tympani and ossicles have been destroyed, and the hearing has persisted, the vibrations must have been conveyed to the parietes of the internal ear through the air in the cavity of the tympanum; and, notwithstanding the charge of "absolute confusion of ideas," brought against such individuals as Scarpa,[1] Magendie, Adelon, and others, who believe that the foramen rotundum receives the undulations of air, we must confess, that the idea of the communication of vibrations through that medium, as well as through the membrane of the foramen ovale, and the osseous parietes of the labyrinth, appears to us most solid and satisfactory.

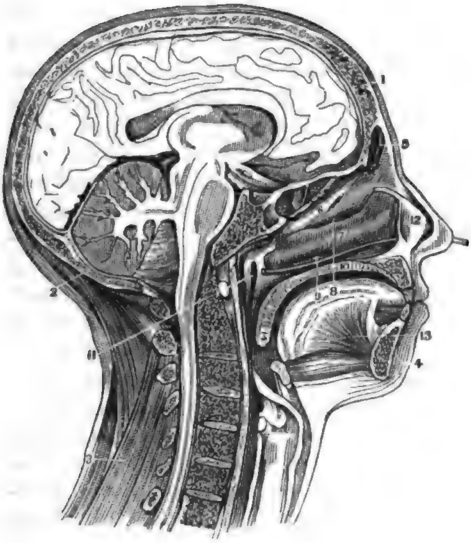
The *ossicles* or *small bones* have given occasion to the wildest speculations. At the present day, they are considered to fulfil one of two functions;—to conduct the vibrations from the membrana tympani,—or to stretch the membranes to which the extremities of the chain are attached. Both these offices are probably executed by them; the malleus receiving the vibrations from the membrana tympani, and conveying them to the incus,—the incus to the os orbiculare,—the os orbiculare to the stapes, and the stapes to the membrane of the foramen ovale, by which they are transmitted to the liquor of Cotunnius. M. Savart conceives, that the chain of ossicles is to the ear what the bridge is to the violin. It has been already observed, that the ossicles are not essential to hearing, although they may be required to perfect it; and that they may be destroyed without deafness being produced, provided the membrane of the foramen ovale remains entire, and the parts within the labyrinth retain their integrity. If, in the removal of the stapes by ulceration or otherwise, the membrane of the foramen should be ruptured, the liquor of Cotunnius would of course escape, and partial or total deafness result. In some experiments instituted by M. Flourens on pigeons, he found, that the removal of the malleus and incus did not have much effect upon the hearing; but when the stapes was taken away it was greatly impaired, and still more so when the membranes of the fenestra ovalis and fenestra rotunda were destroyed.

The *Eustachian tube* is an important part of the auditory apparatus,

[1] Anat. Disquis. de Auditu et Olfactu., Ticin, 1789; and De Structurâ Fenestræ Rotundæ Auris, &c., Mutin., 1772.

and an invariable accompaniment of the membrana tympani, in animals. Without the tube, the membrane would be almost devoid of function. Pathology shows us, in the clearest manner, that its integrity is necessary to audition; and that deafness is the consequence of its closure. Dr. Bostock[1] thinks, "it is perhaps not very easy to ascertain in what mode it acts, but it may be concluded that the proper vibration of the membrana tympani is, in some way, connected with the state of the air in the tube." The name of the cavity to which the tube forms a communication with the external air suggests an easy and sufficient explanation of its use. The *drum* of the ear, like every drum, requires an aperture in some part of its parietes, in order that its membranes may vibrate freely. The Eustachian tube serves this purpose, and its closure produces the same effect upon the membrana tympani at one end of the cylinder, and on the membrane of the foramen ovale at the other, as would be produced on the parchments of the ordinary drum by the closure of its lateral aperture. We can, in this way, account for the temporary deafness, which accompanies severe cases of inflammation of the throat:—the swelling obstructs the Eustachian tube. Dr. Carpenter,[2] however, thinks that the effect of the hole in the side of a drum seems rather to be the communication of the sonorous vibrations of the contained air to the ear of the observer, which are thus transmitted directly through the atmosphere, instead of being weakened by transmission through the walls of the instrument; and hence he concludes, that there is no real analogy between the two cases.

Fig. 76.



Vertical Section of the Head and Neck through the Mesial Line, to show the opening of the Eustachian Tube and its relations to the Pharynx.

1. Section of the os frontis. 2. Section of the os occipitis. 3. Muscles on the back of the neck. 4. Integuments on the chin. 5. Frontal sinus. 6. Middle spongy bone. 7. Inferior spongy bone. 8. Middle meatus of the nose. 9. Inferior meatus of the nose. 10. Thickness of the roof of the mouth and floor of the nostril. 11. Opening of the Eustachian tube. A catheter is introduced in the nostril and about to enter the tube. 12. Cartilaginous nasal septum. 13. Genio-glossus muscle. 14. Soft palate.

During the constant efforts of deglutition the air is renewed in the cavity of the tympanum; and, as the extremities of the Eustachian tube terminate in the pharynx, it enters at a modified temperature. The writer last cited thinks the principal object of the tube seems to be maintenance of the equilibrium between the air within the tympanum

[1] Physiology, 3d edit., p. 721, London, 1836.
[2] Human Physiology, § 357, London, 1842.

and that without, so as to prevent the inordinate tension of the membrane, that would be produced by too great or too little pressure on either side; the effect of which would be impaired hearing.

By closing the nose and mouth, and forcing air from the lungs, we can feel a sensation of fulness in the ear, produced by the pressure of the air against the internal surface of the membrana tympani; and they, who have the membrane perforated, can send tobacco smoke copiously out of the external ear.

Besides this necessary function, the Eustachian tube has been supposed to possess another,—that of serving as a second meatus auditorius, by permitting sonorous vibrations to enter the pharyngeal extremity, and, in this way, attain the middle ear. A simple experiment, first described by M. Pérolle,[1] exhibits the fallacy of this notion. If we carry a watch far back into the mouth, taking care not to touch the teeth, little or no sound will be heard; but if we draw the watch forward, so as to touch the teeth, the ticking becomes distinctly audible. If the pharyngeal extremity acted as a second meatus, the sound ought to be heard better when the watch is placed nearer to it; but such is not the case. On the contrary, it is not until the sonorous body is put in contact with the teeth, that the sound is appreciated. This is effected by the vibrations of the watch being conveyed along the bony parietes until they reach the auditory nerve. Again; if the meatus auditorius externus be completely closed, we cannot hear the voice of one who speaks into the mouth; and can hear but imperfectly our own. The fact of our gaping, when desirous of hearing accurately, has partly led to the belief, that the tube acts as a second meatus. It has been properly remarked, however, that this may be merely an act of expression; and, also, that the meatus auditorius is rendered more open, when we depress the lower jaw, than when it is raised, as may be perceived by inserting the little finger into the meatus, when the jaw is in either situation.

In addition to these functions, it is probable, that the tube acts as a diverticulum for the air in the cavity of the tympanum, when the membrane is agitated by too powerful sounds. The closure of the tube is the cause of that form of deafness, which is relieved by injection of air or other fluids into it—a fact, the knowledge of which has been the foundation of much empiricism. It likewise conveys into the pharynx the mucus secreted by the lining membrane of the tympanum, probably by means of the vibratile cilia on its mucous surface.

Internal Ear.—In the various ways mentioned, the vibrations of a sonorous body reach the internal ear. The membranes of the foramen ovale and foramen rotundum resemble the membrana tympani in their physical characteristics; and when thrown into vibrations communicate the impression to the liquor of Cotunnius contained in the cavities of the internal ear. By this medium, the vibrations are conducted to the auditory nerve, which conveys the impression to the brain.

Almost all the views entertained regarding the sympathetic vibrations of the membrana tympani have been applied to the membrane of the

[1] Hist. et Mém. de la Société Royale de Médecine, tom. iii.

foramen ovale: our knowledge, however, is restricted to the fact, that its tension can be varied by the chain of ossicles, without our being able to specify the circumstances under which this takes place. M. Adelon asserts, that the membrane may be torn, and yet the sense of hearing not be destroyed. This seems scarcely possible, as the liquor of Cotunnius must necessarily escape, and so much morbid action be induced as to render audition impracticable.

The membrane of the foramen rotundum, which forms the medium of communication between the cavity of the tympanum and the cochlea, has no chain of bones to modify its tension. The vibrations into which it is thrown, as well as those of the vestibular membrane, are imparted, as we have seen, to the *liquor of Cotunnius*, which is present in every ear, and appears essential to audition.

Of the precise use of the *vestibule*, *semicircular canals*, and *cochlea*, we have very limited notions. The beauty and complexity of their arrangement has given rise to various conjectures. M. Le Cat[1] considered the lamina spiralis to consist of numerous minute cords, stretched along it, and capable of responding to every tone. M. Magendie[2] affirms, that no one admits the hypothesis regarding the use of this osseo-membranous septum; but he is in error. Sir C. Bell[3] asserts, that the cochlea is the most important part of the organ of hearing; or rather, that it is "the refined and higher part of the apparatus;" and he considers the lamina spiralis as the only part adapted to the curious and admirable powers of the human ear for the enjoyment of melody and harmony. The subject of the musical ear will engage us presently. It may be sufficient to remark, that there is no ratio in animals, between their delicacy of hearing and the degree of complication of the cochlea. The cochlea of the Guinea pig is more convoluted than that of man; yet we can hardly conceive it to have a better appreciation of musical tones; whilst in birds, whose hearing is delicate, the organ is, as we have remarked, simple, and has no spiral arrangement.

Again; the semicircular canals have been compared to organ pipes, adapted for producing numerous tones; and Dr. Young[4] supposes them to be "very capable of assisting in the estimation of the acuteness or pitch of a sound, by receiving its impression at their opposite ends; and occasioning a recurrence of similar effects at different points of their length according to the different character of the sound; while the greater or less pressure of the stapes must serve to moderate the tension of the fluid within the vestibule, which serves to convey the impression." "The cochlea," he adds, "seems to be pretty evidently a micrometer of sound." Another view—to be remarked upon hereafter—is, that their peculiar function is the reception of the impressions by which we distinguish the direction of sounds. All these are mere hypotheses; ingenious, it is true, but still hypotheses; and, in candour, it must be admitted, that we have no positive knowledge of the precise functions of either vestibule, cochlea, or semicircular canals. Our

[1] Traité des Sens, Paris, 1767, or English translation, London, 1750.
[2] Précis, &c., i. 121. [3] Op. citat., ii. 273. [4] Med. Literature, p. 98, London, 1813.

acquaintance with them is limited to this;—that they contain the final expansions of the auditory nerve; and that it is within them, that the nerve receives its impressions from the oscillations of sonorous bodies.

It has been observed, that sonorous vibrations may reach the nerve by the bony parietes, and that the ticking of a watch held between the teeth is, in this way, heard. A blow upon the head is distinctly audible; and Ingrassias[1] relates the case of a person, who had become deaf in consequence of obstruction of the meatus auditorius externus, and yet could hear the sound of a guitar by placing the handle between his teeth, or by making a communication between his teeth and the instrument by means of a metallic or other rod. The physician has recourse to a plan of this kind for detecting if a case of deafness be dependent upon obstructed Eustachian tube; upon some affection of the meatus auditorius externus; or upon insensibility of the auditory nerve, or of the part of the brain where the sensation is accomplished. If the latter be the fact, the ticking of a watch, applied to the teeth, will not be audible, and the case will necessarily be of a hopeless character. If, on the other hand, the sound be perceived, the attention of the physician may be directed, with well-founded expectation of success, to the physical parts of the organ, or to those concerned in the transmission of vibrations. Frequently, it will happen, in such cases, that the Eustachian tube is impervious, and properly directed efforts may succeed in removing the obstruction; or, if this be impracticable, temporary, if not permanent, relief may be obtained by puncturing the membrana tympani, and allowing the aerial undulations, in this way, to reach the middle and internal ear.

Lastly;—as regards the precise *nerve of hearing*. In this sense, we have the distinction between the nerve of general, and that of special sensibility, more clearly perceptible. The experiments of M. Magendie[2] have shown, that the portio mollis of the seventh pair is a nerve of special sensibility;—that it may be cut, pricked, or torn, without exhibiting any general sensibility, and is inservient to the sense of hearing only. The same experiments demonstrate, that it cannot act unless the fifth or nerve of general sensibility be in a state of integrity. If the latter be divided within the cranium, hearing is always enfeebled, and frequently destroyed. The experiments of M. Flourens,[3] to which allusion has been made, led him to infer that the rupture of the cochlea was of less consequence than that of the semicircular canals. Laceration of the nerve, distributed to the vestibule, enfeebled the hearing, and its total destruction was followed by irreparable deafness. For these, and other reasons afforded by comparative anatomy, M. Lepelletier[4] infers, that, in the higher organisms, the vestibule and its nerve constitute the essential organ of impression; the other parts being superadded to perfect the apparatus.

An interesting case of malformation has been related by Professor

[1] De Ossibus, p. 7. Also, Boerhaave, Prælectiones, iv. 415, and Haller, Element. Physiol. tom. v. p. 253, Lausann., 1763.
[2] Précis, &c., 2de édit., i. 114.
[3] Expériences sur le Système Nerveux, p. 42, Paris, 1825, or 2de édit., Paris, 1842.
[4] Traité de Physiologie Médicale et Philosophique, iii. 143, Paris, 1832.

Mussey,[1] of Cincinnati, which shows, that other nerves besides the portio mollis of the seventh pair may, under unusual circumstances, be inservient to audition. In this case there was no appearance of meatus auditorius externus in either ear, and yet the man, twenty-seven years of age, although his sense of hearing was too obtuse for low conversation, could hear sufficiently well to prosecute his business—that of a bookseller—without material inconvenience. By covering the head with layers of cloth, the hearing was manifestly obscured. On speaking to him with one end of a stick in the speaker's mouth, whilst the other end was applied in succession to different parts of the head and face, it was found, that the part over the mastoid process conducted sound most readily; and that the parts corresponding with the upper two-thirds of the occipital, the mastoid plate of the temporal, and the posterior half of the parietal bone, transmitted sounds more readily than the anterior half of the scalp, the forehead, temples, or any other part of the face. Professor Mussey infers, from the results of his observations on this case, that the nerves, derived from the spinal cord below the foramen magnum of the occipital bone, and reflected in profusion over the scalp, were concerned in this unusual function, and that the branches of the fifth nerves were probably the seat of the peculiar faculty on the face.[2] A case also was communicated to the author by the Rev. Dr. Parker, of Macao, in which there was no evidence of external ear. The hearing was very indistinct. Under the idea, that the internal organs were perfect, and that, to render the hearing so, it was only necessary to perforate the integument so as to admit the air to the tympanum, Dr. Parker, at the request of the youth and his parents, determined to perforate one ear. In accordance with Chinese prejudice in favour of the cautery, caustic potassa was applied, and "as soon as the slough from the first applications was removed, the hearing was surprisingly improved." No cavity, however, could be discovered. After different operations, he was able to hear a whisper.[3]

The immediate function of the sense of hearing is to appreciate sound; and we may apply to it what has been said of the other senses; that, in this respect, it cannot be supplied by any other; is instinctive; requires no education; and is exerted as soon as the parts have attained a due degree of development.

Amongst the advantages afforded by the possession of this sense, which has been well termed *intellectual*, are two of the highest gratifications we enjoy,—the appreciation of music, and the pleasures of conversation. To it we are indirectly indebted for the use of verbal language—the happiest of all inventions—as it has been properly termed; and to which we shall have to advert in the course of our inquiry into the animal functions.

Metaphysicians and physiologists have differed widely in their views regarding the organs more immediately concerned in the appreciations in question. Many, for example, have referred the faculty of music to the ear; and hence, in common language, we speak of an individual,

[1] American Journal of the Medical Sciences, Feb., 1838, p. 378.
[2] A similar case by Mr. Swan is in Medico-Chirurgical Transactions, vol. xi.
[3] First Report of the Ophthalmic Hospital, Canton, Feb., 1826.

who has a "*musical ear*," or the contrary. Others, more philosophically, have considered, that the faculty is encephalic; that the ear is merely the instrument for conveying the sonorous undulations, which, in due order, constitute melody; but that the appreciation is ultimately effected in the brain. "That it," (the power of distinguishing the musical relations of sounds,) says Dr. Brown,[1] "depends chiefly, or perhaps entirely, on the structure or state of the mere corporeal organ of hearing, which is of a kind, it must be remembered, peculiarly complicated, and therefore susceptible of great original diversity in the parts, and relations of the parts that form it, is very probable; though the difference of the separate parts themselves, or of their relations to each other, may, to the mere eye, be so minute, as never to be discovered by dissection." Many physiologists of eminence have regarded the complex internal ear as the seat of the faculty; some looking to the cochlea; others to the semicircular canals; and but few referring it to the brain. Sir C. Bell, indeed, asserts, that "we are not perhaps warranted in concluding, that any one part of the organ of hearing bestows the pleasures of melody and harmony, since the musical ear, though so termed, is rather a faculty depending on the mind." Yet afterwards he adds:—"We think that we find in the lamina spiralis (of the cochlea) the only part adapted to the curious and admirable powers of the human ear for the enjoyment of melody and harmony. It is in vain to say, that these capacities are in the mind and not in the outward organ. It is true, the capacity for enjoyment or genius for music is in the mind. All we contend for is, that those curious varieties of sound, which constitute the source of this enjoyment, are communicated through the ear, and that the ear has *mechanical* provisions for every change of sensation."[2] A cherished opinion of Sir Everard Home[3] on this subject has been given before. Conceiving the membrane of the tympanum to be muscular, he considers the membrana tympani, with its tensor and radiated muscles, to resemble a monochord, "of which the membrana tympani is the string; the tensor muscles the screw, giving the necessary tension to make the string perform its proper scale of vibrations; and the radiated muscle, acting upon the membrane, like the movable bridge of the monochord, adjusting it to the vibrations required to be produced;" and he adds: "the difference between a musical ear and one which is too imperfect to distinguish the different notes in music will appear to arise entirely from the greater or less nicety with which the muscle of the malleus renders the membrane capable of being truly adjusted. If the tension be perfect, all the variations produced by the action of the radiated muscle will be equally correct, and the ear truly musical." In this view,—as unsatisfactory in its basis as it is in some of the details,—Sir Everard completely excludes, from all participation in the function, the internal ear, to which the attention of physiologists, who consider the faculty to be seated in the ear, has been almost exclusively directed.

[1] Lectures on the Philosophy of the Human Mind, Edinb., 1820; or Amer. edit., vol. i. p. 207. Boston, 1826.

[2] Anat. and Physiol., 5th Amer. edit., by Godman, ii. 273. New York, 1829.

[3] Lect. on Comp. Anat., iii. 268.

A single case, detailed by Sir Astley Cooper,[1] prostrates the whole of the ingenious fabric erected by Sir Everard. Allusion has already been made to the old established fact, that the membrane of the tympanum may be destroyed without loss of hearing necessarily following. Sir Astley was consulted by a gentleman, who had been attacked, at the age of ten years, with inflammation and suppuration in his left ear, which continued discharging matter for several weeks. In the space of about twelve months after the first attack, symptoms of a similar kind took place in the right ear, from which matter issued for a considerable time. The discharge, in each instance, was thin, and extremely offensive; and in it, bones or pieces of bones were observable. In consequence of these attacks he became deaf, and remained so for three months. The hearing then began to return; and in about ten months from the last attack, he was restored to the state he was in when the case was published. Having filled his mouth with air, he closed his nostrils and contracted the cheeks; the air, thus compressed, was heard to rush through the meatus auditorius with a whistling noise, and the hair, hanging from the temples, became agitated by the current of air that issued from the ear. When a candle was applied, the flame was agitated in a similar manner. Sir Astley passed a probe into each ear, and thought the membrane of the left side was totally destroyed, as the probe struck against the petrous portion of the temporal bone. The space, usually occupied by the membrana tympani, was found to be an aperture without one trace of membrane remaining. On the right side, also, a probe could be passed into the cavity of the tympanum; but, on this side, some remains of the circumference of the membrane could be discovered, with a circular opening in the centre, about a quarter of an inch in diameter. Yet this gentleman was not only capable of hearing everything that was said in company, but was nicely susceptible to musical tones; "he played well on the flute, and had frequently borne a part in a concert; and he sang with much taste and perfectly in tune."

But, independently of these partial objections, the views which assign musical ear and acquired language to the auditory apparatus, appear liable to others that are insuperable. The man who is totally devoid of musical ear hears the sound distinctly. His sense of hearing may be as acute as that of the best musician. It is his appreciation that is defective. He hears the sound; but is incapable of communicating it to others. The organ of appreciation is—in this, as in every other sense—the brain. The physical part of the organ may modify the impression that has to be made upon the nerve of sense; the latter is compelled to transmit the impression as it receives it; and it is not until the brain has acted, that perception takes place, or that any idea of the physical cause of the impression is excited in the mind. If, from faulty organization, such idea be not formed in the case of musical tones, the individual is said not to possess a musical ear; but the fault lies in his cerebral conformation. We do not observe the slightest relation between musical talent and delicacy of hearing. The best

[1] Philosoph. Transact. for 1800, p. 151, and for 1801, p. 435.

musicians have not necessarily the most delicate sense; and, for the reasons already assigned, it will be manifest, why the idiot, whose hearing may be acute, is incapable of singing, as well as of speaking. Again, we do not see the least ratio in animals between the extent and character of their music and the condition of their auditory sense. We are compelled, then, to admit, that the faculties of music and speech are dependent upon organization of the brain; that they require the ear as an instrument; but that their degree of perfection is by no means in proportion to the delicacy of the sense of hearing. In these opinions, MM. Gall,[1] Broussais,[2] Adelon,[3] and other distinguished physiologists concur. "Speech," says M. Broussais, "is heard and repeated by all men, who are not deprived of the auditory sense; because they are all endowed with cerebral organization fit to procure for them distinct ideas on the subject. Music, when viewed as a mere noise, is also heard by every one; but it furnishes ideas, sufficiently clear to be reproduced, to those individuals only whose frames are organized in a manner adapted to this kind of sensation."

Yet, although we must regard the musical faculty to be intellectual, and consequently elevated in the scale, it is hardly necessary to say, that the want of it is no evidence of that mental and moral degradation, which has been depicted by poets and others.

"The man that hath no music in himself,
Nor is not moved with concord of sweet sounds,
Is fit for treasons, stratagems, and spoils;
The motions of his spirit are dull as night,
And his affections dark as Erebus:
Let no such man be trusted."

SHAKSPEARE, "*Merchant of Venice*," v. i.

"Is there a heart that music cannot melt?
Alas! how is that rugged heart forlorn!
Is there, who ne'er those mystic transports felt
Of solitude and melancholy born!
He needs not woo the muse; he is her scorn.
The sophist's rope of cobweb he shall twine;
Mope o'er the schoolman's peevish page; or mourn,
And delve for life in mammon's dirty mine;
Sneak with the scoundrel fox, or grunt with glutton swine."

BEATTIE, "*Minstrel.*"

In the classification of the objects of human knowledge, music has been ranked with poetry; but we meet with striking evidences of their wide separation. Whilst the professed musician is frequently devoid of all poetical talent, many excellent poets have no musical ear. Neither does the power of discriminating musical tones indicate, that the possessor is favoured with the finer sensibilities of the mind; nor the want of it prove their deficiency. It has been a common remark, that amongst professed musicians, the intellectual manifestations have been singularly and generally feeble; a result partly occasioned by their attention having been almost entirely engrossed from childhood by their

[1] Sur les Fonctions du Cerveau, v. 96. Paris, 1825.
[2] Traité de Physiologie, translated by Drs. Bell and La Roche, p. 84, 3d Amer. edit., Philad., 1832.
[3] Op. citat., i. 383.

one favourite pursuit, but not perhaps to be wholly explained by this circumstance; and, whilst we find them often unmarked by any of the kindlier sympathies, we see those, that are "not moved with concord of sweet sounds," alike distinguished as philosophers and philanthropists.

The defect, in these cases, differs probably, in an essential manner, from one to which attention has been drawn by the late Dr. Wollaston,[1] who has detailed many curious facts, regarding what he terms a peculiarity in certain ears, which seem to have no defect in their general capacity for being impressed by sound, or in the perception of musical tones; but are insensible to very acute sounds. This insensibility commences when the vibrations have attained a certain degree of rapidity; beyond which all sounds are inaudible to ears thus constituted. Thus, according to Dr. Wollaston, certain persons cannot hear the chirp of the grasshopper; others, the cry of the bat; and he refers to one case, in which the note of the sparrow was inaudible. He himself was incapable of hearing any sound higher than six octaves above the middle E of the piano forte. The defect would, at first sight, appear to be referable to the physical part of the ear, rather than to the auditory nerve, or to the part of the brain concerned in the appreciation of sounds;—the vibrations that are performed with great rapidity not being responded to by the parts of the organ destined for that purpose; and, consequently, never reaching the auditory nerve. Researches, however, by M. Savart,[2]—a most dexterous and ingenious experimenter,—seem to show that the defect in the appreciation of acute sounds, in such cases, is not owing to their *acuteness* but to their *feebleness;* that if the sound can be made sufficiently intense, the ear is capable of hearing a note of upwards of forty thousand simple oscillations in a second; and that the cases referred to by Dr. Wollaston are, consequently, owing to defective hearing, rather than to insensibility to very *acute* sounds.

Another acquired perception of the ear is that of forming a judgment of the *distance* of bodies. This we do by attending to the loudness of the sound; for we instinctively believe, that a loud sound proceeds from a body near us, and a feeble sound from one more remote. This is the cause of numerous acoustic errors, in spite of all reason and experience. In the theatres, the deception is often admirably managed, when the object is to give the idea of bodies approaching. The sound—that of martial music, for example—is rendered faint and subdued; and, under such circumstances, appears to proceed from remote distance; and, by adding gradually and skilfully to its intensity, we are irresistibly led to the belief that the army is approaching; and the illusion is completed by the appearance of the military band on the stage, allowing its soul-inspiring strains to vibrate freely in the air. In like manner, we are deceived by the ventriloquist. He is aware of the law that guides us in our estimation of distance; and, by skilfully modifying the intensity of his voice, according as he wishes to make

[1] Philosophical Transactions for 1820, p. 306.
[2] Journal de Physiologie de Magendie, v. 367.

the sound appear to proceed from a near or a distant object, he irresistibly leads us into acoustic error.

Education or experience is required to enable us to appreciate distances accurately by this sense; as well as to judge of their position. In the case, detailed by M. Magendie,[1] of a boy, who, after having been entirely deaf until the age of nine, was restored to hearing by M. Deleau, by means of injections thrown into the cavity of the tympanum through the pharyngeal extremity of the Eustachian tube, one of the most remarkable points was his difficulty in acquiring a knowledge of the position of sonorous bodies. In forming an accurate judgment on this subject we seem to require the use of both ears. In all other cases an impression made upon one only would perhaps be sufficient. The common opinion is, that to judge of the direction of a sound we compare the intensity of the impression on each ear, and form our deductions accordingly; and that if we close one ear we are led into errors, which are speedily dissipated by employing both. Still we are often deceived even under these last circumstances, and are compelled to call in the aid of sight. The blind afford us striking examples of accuracy, in their perceptions by the ear. In the Belisar of Zeune, the case of a blind man is cited from Diderot; who, guided by the direction of the voice, struck his brother in a quarrel on the forehead, with a missile, which brought him to the ground.[2]

Mr. Wheatstone supposes, that the perception we have of the direction of sounds arises solely from the portion transmitted through the solid parts of the head, which, by affecting the three semicircular canals, situate in planes at right angles with each other, with different degrees of intensity, according to the direction in which the sound is transmitted, suggests to the mind the corresponding direction. If the sound be transmitted in the plane of either of the semicircular canals, the nervous matter in that canal will be more strongly acted on than that in either of the other two; and if in any plane intermediate between two of the rectangular planes, the relative intensities in these two canals corresponding therewith will vary with the direction of the intermediate plane;[3] and it has been regarded by Dr. Carpenter[4] as a powerful argument in support of this view, that in almost every instance in which these canals exist at all, they hold the same relative position to each other as in man; their three planes being nearly at right angles to one another. He properly, however, adds, that the idea must be regarded as a mere speculation, the value of which cannot be decided without an increased knowledge of the laws according to which sonorous vibrations are transmitted.

If these vibrations, before reaching the ear, be deflected from their course, we are liable to deception, mistaking the echo for the direct or radiant sound.

The ideas of *magnitude* acquired by the ear are few, and to a trifling extent only. They occasionally enable the blind to judge of the size

[1] Journal de Physiologie, v. 223.
[2] Rudolphi, Grundriss der Physiologie, s. 149, Berlin, 1823.
[3] Journal of Science, New Series, ii. 67, London, 1827.
[4] Human Physiology, § 359, London, 1842.

of apartments, and this they sometimes do with much accuracy. It is well known, that if a sound be confined within a small space, it appears louder than when the sonorous undulations can extend farther; hence the greater noise caused *directly* by a pistol fired in a room than in the open air. The sound *indirectly* produced will necessarily be modified by the different reflections or echoes, that may be excited. By attending to these circumstances—to the loudness of the voice and the intensity of the reverberations occasioned by the walls, and calling into aid experience under similar circumstances,—in other words, by effecting a strictly intellectual process,—the blind attain the knowledge in question.

The *velocity* of a body is indicated by the rapid succession of the vibrations that impress the ear, as well as by the change in their intensity, if the body be moving along a surface or through the air. A carriage, approaching with great velocity, is detected by the ear, from the rapidity with which the wheels strike against intervening obstacles; and by the gradual augmentation in the intensity of the sound produced. When opposite to us the intensity is greatest; and a declension gradually takes place until the sound is ultimately lost in distance.

Lastly;—by audition we form some judgment of the nature of bodies by the difference in the sounds emitted. It has been already remarked, that the *timbre* or *quality of sound* can be accurately appreciated. By this *quality* we distinguish between the sound of wood or metal; of hollow or solid bodies, &c.; but in all these cases we are compelled to call into aid our experience—without which we should be completely at a loss—and to execute a rapid, but often very complicated, intellectual operation.

Audition may be exercised *passively* as well as *actively;* hence the difference between simply *hearing*, and *listening*. We cannot appreciate, in man, the precise effects produced on the different portions of the ear by volition;—whether, for example, the advantage be limited to the better direction given to the ear, as regards the sonorous body, and to avoiding all distraction by confining the attention to the impressions made on the sense; or whether, by it, the pavilion may not be made somewhat more tense by the contraction of its intrinsic and extrinsic muscles;—whether the membrana tympani, and the membrane of the foramen ovale may be modified by the contraction of the muscles of the ossicles; or, in fine, the auditory nerve be rendered better adapted for the reception of the impression, and the brain for its appreciation. All these points are unsusceptible of direct observation and experiment; and are, therefore, enveloped in uncertainty. In some animals—as the horse—the outer ear becomes an acoustic instrument under the guidance of volition; and is capable of being turned in every direction in which a sonorous body may be placed.

Like other senses, that of hearing is largely improved by education or cultivation. The savage, accustomed, in the stillness of the forest, to listen to the approach of enemies or his prey, has the sense so delicate as to hear sounds, that are inaudible to one brought up in the din of the busy world. The blind, for reasons more than once assigned,

afford examples of extreme delicacy of this as well as of their other senses. They are necessarily compelled to cultivate it more; and, lastly, the musician, by education, attains the perception of the nicest shades of musical tones. The aptitude is laid in cerebral organization, and is developed by the education of the instrument—the ear—as well as of the encephalic or intellectual organ, without which, as we have seen, no such appreciation could be accomplished.

SENSE OF SIGHT OR VISION.

The immediate function of the sense of sight is to give us the notion of light and colours. Like the other senses, it is a modification of that of touch, whether we regard the special irritant—light—as an emanation from luminous bodies, or as the vibration of a subtile, ethereal fluid, pervading all space. Under the latter theory it would most strongly resemble the sense last considered.

The pleasures and advantages derived by the mind through this inlet, are of so signal a kind as to render the organ of vision a subject of universal interest. Every one, who lays the slightest claims to a general education, has made it more or less a subject of study, and is not unfrequently better acquainted with its structure and properties than the medical practitioner. Complicated as its organization may seem, it is, in action, characterized by extreme simplicity; yet, "in its simplicity," as Dr. Arnott[1] has remarked, "so perfect, so unspeakably perfect, that the searchers after tangible evidences of an all-wise and good Creator have declared their willingness to be limited to it alone, in the midst of millions, as their one triumphant proof." Into this structure we shall inquire, so far as is necessary for our purpose, after having described the general properties of light; and then detail the mode in which its various functions are accomplished, and the knowledge derived by the mind through its agency.

The eye is the organ of vision. It varies materially in different animals;—in some, consisting of a simple capsule, with the final expansion of the nerve of sight distributed on its interior, and communicating externally by means of the transparent cornea, which admits the light. It is in this simple state that M. de Blainville[2] assimilates it to a bulb of hair, modified for the new function it has to execute. In man, and the upper classes of animals, the organ is much more complicated in its structure; and in it we have a still clearer example of the distinction between the physical, and the nervous or vital part of the apparatus, than in any of the other organs of sense,—the former consisting of transparent tunics, and humours, which modify the light according to the laws of optics;—the latter being a production or expansion of nervous structure, for the reception of the impression of light, and for conveying such impression to the proper part of the encephalon. There is, besides, attached to the organ, a number of accessory parts or *tutamina*, which are more or less concerned in the proper performance of the function. It will be necessary, therefore, to

[1] Elements of Physics, 2d Amer. edit., vol. ii. P. i. p. 161, Philad., 1836.
[2] De l'Organization des Animaux, Paris, 1825.

give a succinct view, not only of the eye, properly so called, but also of these accessory organs, which serve to lodge, move, protect, and lubricate it. The description will not, however, be clearly understood, without premising some general observations on the properties of light, especially as regards its refraction, on which the phenomena of vision are greatly dependent.

1. LIGHT.

The sun and the fixed stars are the great sources of light. It is given off, also, from substances in a state of combustion, and from phosphorescent bodies; and, by entering the eye directly, or after various reflections or refractions, impinges on the optic nerve, and gives the sensation of light.

Two main opinions have been entertained regarding the nature of light; the one, propounded by Newton—that it consists of extremely minute particles, emanating from luminous bodies; the other—that of Des Cartes, Hook, Huygens, Euler, and others,—that it is a subtile, eminently elastic fluid—an ether—pervading all space; the elastic molecules of which, when put in motion by the oscillations of bodies, impress the eye as sonorous vibrations affect the ear. It is not for us to discuss this question of higher physics. We may merely remark, that difficulties attend both hypotheses. According to that of Des Cartes, it is not easy to explain, why an opaque body should prevent the undulations from reaching the eye,—or the change of direction, which light experiences in passing from one medium into another; whilst, according to that of Newton, it is difficult to conceive, how a luminous body, as the sun, can shed its immense torrents of light incessantly, without undergoing rapid diminution; and how, with the extreme velocity of light, these particles should not be possessed of sensible momentum; for it has been found that a large sunbeam, collected by a burning-glass, and thrown upon the scale of a balance of extreme delicacy, is insufficient to disturb the equilibrium. To the hypothesis of Newton it has been objected, that the particles being reflected by thousands of bodies, and in innumerable directions, would necessarily jostle and interfere with each other. This objection is not, however, as valid as it appears at first sight. It will be seen hereafter, that the impression of a luminous object remains upon the retina for the sixth part of a second. Admitting it, however, to impress the eye for the $\frac{1}{300}$th part, three hundred particles, per second, would be sufficient to excite a constant and uniform sensation of the presence of light; and since, as we shall find, it traverses sixty-seven thousand leagues in a second of time, if we divide this by three hundred, we shall find a space of six hundred and seventy miles between each particle; a distance equal to that—in a straight line—between New York and Savannah; and if we suppose six particles to be sufficient per second, each will be separated from the other by a space of thirty-three thousand five hundred miles!

Without deciding in favour of either of the great theories, that of Newton admits of more easy application to our subject, and will, therefore, be employed in the various explanations that may be required.

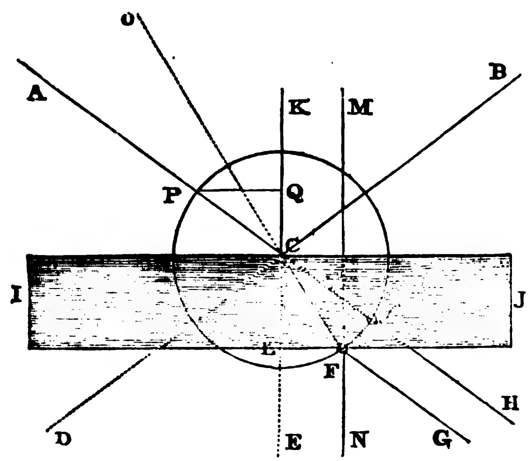
Light, then, proceeding from a luminous body, impinges on the substances that are within its sphere; and these, by reflecting the whole or a part of it to the eye, become visible to us. In its course, direct or reflected, its velocity is almost inconceivable. From observations made on the eclipses of Jupiter's satellites, by Römer, Cassini, and other astronomers, it has been calculated, that the light of the sun is eight minutes and thirteen seconds in its passage from that luminary to the earth. The distance between the earth and the sun is thirty-three millions of leagues, so that the velocity of light is sixty-seven thousand leagues, or two hundred thousand miles per second; in other words, in the lapse of a single second it could pass between Washington and Albany—supposing the distance to be three hundred miles—seven hundred times; and could make the tour of the globe in the time it takes us to wink. In consequence of this extreme velocity,—in all calculations, regarding the light from bodies on the surface of the globe, it is presumed to reach the eye instantaneously; for, granting that a luminous body at Albany could be seen at Washington, the light from it would reach the eye in the $\frac{1}{700}$th part of a second. Inconceivable as this velocity is, it is far surpassed by that of the attractive force exerted between the heavenly bodies. "I have ascertained," says M. La Place, "that between the heavenly bodies all attractions are transmitted with a velocity, which, if it be not infinite, surpasses several thousand times the velocity of light; and we know that the light of the moon reaches the earth in less than two seconds." An annotator on the works of this distinguished mathematician is more definite; affirming, "that the gravific fluid passes over one million of the earth's semi-diameters in a minute of time." Its velocity is eight millions of times greater than that of light.

A series of particles, succeeding each other in a straight line, is called a *ray* of light. Light which proceeds from a radiant point, forms diverging *cones*, which would be prolonged indefinitely did they not meet with obstacles. In its course, it loses its intensity according to a law, which seems applicable to all influences radiating from a centre. If a taper be placed in the middle of a box, each one of whose sides is a foot square, all the light must impinge upon the sides of the box; if it be placed in a box, whose sides are two feet square, the light will shine upon them from double the distance, but it will be distributed over four times the surface. The intensity of the light, then, in this case, as in every other, diminishes according to the square of the distance from the luminous body. According to this rule, those planets which are nearer the sun than ours must receive the light and also the heat—for the same law applies to caloric—in much greater intensity; whilst the more distant luminaries can receive but little caloric, or light, in comparison with the earth; hence, perhaps, the necessity for the satellites by which they are accompanied, and by whose agency the light of the sun is reflected to the planet, and the deficiency in some measure compensated.

In proceeding from a luminous body, *rays*, *cones*, or *pencils of light* must traverse intermediate bodies, in order to reach the eye. These bodies are called *media*. Air is the common medium; and when, in

this way, the light has attained the exterior of the organ, the farther transmission is effected through different transparent humours, which consequently form so many *media*. In its course through media, light may remain unmodified: it may proceed in the same straight line; or it may meet with an obstacle which arrests it altogether, or *reflects* it; or, again, it may traverse media of different natures and densities, and be made to deviate from its original course, or be *refracted*.

Fig. 77.



Reflection and Refraction of Light.

When a ray of light falls upon an *opaque* body, as upon a bright metallic or other mirror, it is reflected from the mirror, in such a manner, that the angle made by the incident ray with a perpendicular to the surface of the medium at the point of incidence, is exactly equal to that made by the reflected ray with the same perpendicular. Suppose I J to represent a plate of polished metal, or glass, rendered opaque by a metal spread upon its posterior surface, as in the common looking-glass. The rays, proceeding from an observer at K, will be reflected back to him in the same line K C; that is, in a line perpendicular to C, the point of incidence. The observer will, therefore, see his own image; but, for reasons to be mentioned hereafter, under optical illusions, he will seem to be as far behind the mirror as he really is before it, or at E. Suppose, on the other hand, that the observer is at A, and that a luminous body is placed at B; in order that the rays, proceeding from it, shall impinge upon the eye at A, it is necessary that the latter be directed to that point of the mirror from which a line, drawn to the eye, and another to the object, will form equal angles with the perpendicular; in other words, the angle B C K, or *angle of incidence*, must be equal to the *angle of reflection*, A C K. In this case, again, the object will not appear to be at B, but in the prolongation of the line A C, at H, as far from the point of incidence C as B is.

Except in the case of illusions, the study of the reflection of light or *catoptrics* does not concern vision materially. It is on the principles of *dioptrics*, that the chief modifications are effected on the progress of the light through the physical part of the organ; and, without a knowledge of these principles, the subject would be totally unintelligible. It is necessary, therefore, to dwell at some length on this topic.

Whenever a ray of light passes through *diaphanous* or *transparent*

bodies of different densities it is bent or made to deviate from its course; and such deviation is called *refraction;* the ray is said to be *refracted;* and, owing to its being susceptible of such refraction, is held to be *refrangible.* The point, at which a ray enters the medium, is called the *point of immersion;* and that, by which it issues from such medium, the *point of emergence.* Instead of considering the medium I J opaque, let it be regarded as transparent. C, in this case, will be the point of immersion for the incident rays that meet there; and L and F will be the points of emergence for the rays K E and A C F G, respectively. If a ray of light, as K C, falls perpendicularly on the surface of any medium, it continues its course through it without experiencing any modification, and emerges in the same straight line. Hence a body at L will appear in its true direction and distance to an observer at K looking directly downwards on a pool of water, I J. If, on the other hand, a ray, as A C, after having passed through air, falls obliquely upon the surface of the water B;—by entering a medium of different density, it is deflected from its course; and, instead of proceeding in the direction C H, it is refracted, at the point of immersion, in the direction C F—that is, *towards* the perpendicular K E. If, again, the ray emerges at F into a medium of the same density as that through which it passed in the course A C, it will proceed in a line parallel to A C, or in the direction F G, or will wander *from* the perpendicular. The cause of this difference in the deflections produced by different media is not easy of explanation. The fact alone is known to us, that bodies refract light differently according to their densities and nature. If the light proceeds from a rarer to a denser medium, it is attracted or refracted *towards* the perpendicular; if, on the contrary, it passes from a denser to a rarer medium, it is refracted *from* the perpendicular. The ray A C proceeded from a rarer medium,—the air,—into a denser, I J—water; it was refracted in the direction C F, towards the perpendicular K E. On emerging at F, circumstances were reversed; it wandered from the perpendicular M N, and in the direction F G, parallel to A C, because the media, above and below I J, were identical. We can now understand, why water, saline solutions, glass, rock-crystal, &c., have higher refractive powers than air. They are more dense.

The nature or character of bodies greatly influences their refractive powers. Newton observed this in his experiments, and has furnished science with one of its proudest trophies, by his prognostic, in the then infant state of chemistry, that water and the diamond would be found to contain combustible ingredients. The diamond or *brilliant* is one of the most refractive of known substances, and this is one of the sources of its brilliancy. The opinion of Newton, it is hardly necessary to say, has been triumphantly confirmed.

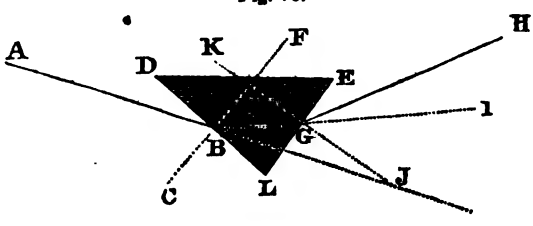
This refraction of rays, that fall obliquely upon a medium, gives rise to numerous optical illusions. The ray proceeding from F, in the bent course F C A, will impinge on an eye at A; and the object F will appear to be at *f.* The pool will consequently seem shallower. In like manner, an object O in the air would not be perceptible to an eye in the water at F, in the direction O C F; whilst one at A would be dis-

tinctly visible,—the ray from it proceeding in the direction A C F, but appearing to come straight to the eye in the direction O C F.

All transparent bodies, at the same time that they refract light, reflect a portion of it. This is the cause of the reflections we notice in the glass of windows, and of the image perceptible in the eye. The same substance has always the same refractive power, whatever may be its shape:—in all cases, the sine of the angle of refraction holding the same ratio to the sine of the angle of incidence, whatever may be the incidence. The *angle of incidence* is the angle formed by the incident ray with a perpendicular raised from the point of immersion; the *angle of refraction* that formed by the refracted portion of the ray with the same perpendicular. In Fig. 77, A C K is the angle of incidence of the ray A C; and L C F the angle of refraction. The sines of these angles respectively are the lines P Q and L F. But although media may refract the rays of light equally, the form of the refracting body materially modifies their arrangement. The perpendiculars to the surface may approach or recede from each other; and if this be the case the refracted rays will approach or recede from each other likewise.

Where the body has plane and parallel surfaces, as the glass of our windows, the refraction, experienced by the ray on entering the glass, is corrected by that which occurs on its emergence; the light does not, therefore, proceed in one straight line, but in parallel lines separated by a space dependent upon the thickness of the refracting body, and the obliquity of the incident ray. If the medium be thin as in a pane of glass, the rays do not appear deflected from their original direction. In Fig. 77, the interval between the direct ray and the ray A C F after its emergence is that between G and H. If the surfaces of the diaphanous body be plane, but inclined towards each other, as in the common prism; the refraction experienced by the ray, on emerging, instead of correcting that experienced during its passage through the body, is added to it; and the rays are deflected from their course to an extent equal to the sum of the two refractions. The ray A B, Fig. 78, after impinging upon the side D L of the prism at B, instead of continuing its course in the direction B J, is refracted *towards* the perpendicular C B F,—the medium being denser than air, and on emerging into the rarer medium, instead of continuing its course in the direction G I, it is refracted in the line G H, or *from* the perpendicular K J. Again, if the surfaces of the medium be convex, the rays are so situate, after refraction, as to converge behind the refracting body into a point called the *focus*, which is nearer to the medium the less the divergence of the rays, or in other words, the more distant the luminous object.

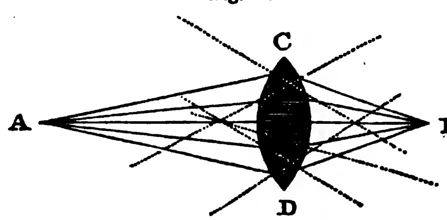
Fig. 78.



Prism.

Fig. 79 exhibits a pencil of rays, proceeding from a radiant point at A, and meeting at a focus at B; the dotted lines being the perpendiculars drawn to the surface at the points of immersion and emergence. Lastly; if the surfaces of the medium be concave, as in Fig. 80, the luminous rays, proceeding from a radiant point as at A, are rendered so divergent, that if we look for a focus here it must be anterior to the medium or at G.

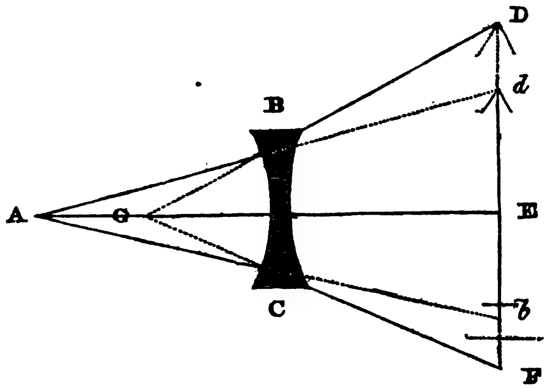
Fig. 79.



Double Convex Lens.

A knowledge of these facts has given occasion to the construction of numerous invaluable optical instruments, adapted to modify the luminous rays so as to change the situation in which bodies are seen; to augment their dimensions; and to render them more luminous and visible, when remote and minute. It is to this branch of science that we are indebted for some of the most important information and advantages, that we possess in the domains of science and art. The simplest of these instruments are bodies shaped like a lentil, and hence called *lenses*. They are composed of two segments of a sphere. The medium in Fig. 79 is a *double convex;* that in Fig. 80, a *double concave lens*. The manner in which they modify the course of the luminous rays passing through them has been sufficiently described.

Fig. 80.

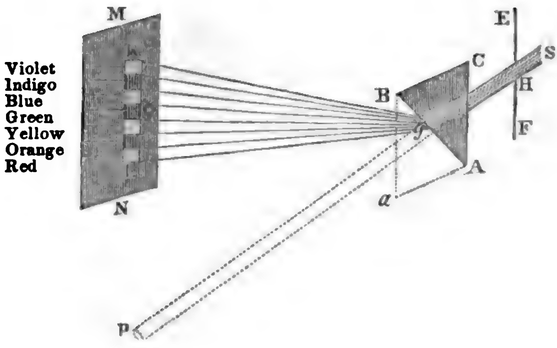


Double Concave Lens.

The study of the refraction of light leads to the knowledge of an extremely important fact; which, when it was first made known by Newton, excited universal astonishment;—that a ray of light is itself composed of several coloured rays differing from each other in their refrangibility. If a beam of the sun's light be admitted through the hole of a window-shutter, E F, Fig. 81, into a dark chamber, it will proceed in a direct line to P, and form a white spot upon the wall, or on a whitened screen placed there for the purpose. But if a glass prism, B A C, be placed, so that the light may fall upon its surface, C A, and emerge at the same angle from its second surface, B A, in

the direction g G, the beam will expand; and if, after having emerged, it be received on the whitened screen, M N, it will be found to occupy a considerable space; and, instead of the white spot, there will be an oblong image of the sun, K L, consisting of seven colours;—*red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet*. Each of these colours admits of no farther decomposition when again passed through the prism; and the whole lengthened image of the sun is called the *prismatic* or *solar spectrum*. In this dispersion of the coloured rays, it will be observed that the red ray is the least turned from its course; and is hence said to be the least refrangible; whilst the violet is most so.

Fig. 81.



Prismatic Spectrum.

Such is the spectrum, as depicted by Newton: since his time, it has, by some, been reduced to three colours,—*red*, *yellow*, and *blue;* as certain of the colours can be composed from others,—the green, for example, from the blue and yellow. Wollaston made it to consist of four; *red*, *green*, *blue*, and *violet;* Sir J. Herschel of four; *red*, *yellow*, *blue*, and *violet:* and, more recently, Sir David Brewster has restricted it to three; *red*, *yellow*, and *blue*. The causes which have led to these various divisions, it is not our province to explain.

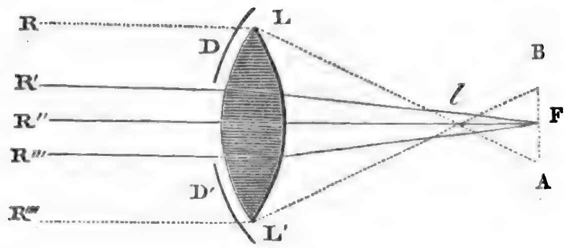
Each of the rays, of which the spectrum is composed, appears to have a different calorific and chemical action; but this also is a subject, that nowise concerns the function under consideration.

The decomposition of light into its constituent rays enables us to explain the cause of the colour of different substances. When white light impinges upon a body, the body either absorbs all the rays that compose it; reflects all; or absorbs some, and reflects others. If it reflects the whole of the light to the eye, it is of a *white* colour; if it absorbs all, or reflects none, it is *black;* if it reflects only the red ray, and absorbs all the rest, it is *red;* and so of the other colours. The cause, why one body reflects one ray, or set of rays, and absorbs others, is unknown. It is conceived to be owing to the nature and particular arrangement of its molecules; which is probable. But we are still as much in the dark as ever. It is accounting for the *ignotum per ignotius*.

Two other points require a brief notice, being intimately concerned in vision;—the *aberration of sphericity*, and *aberration of refrangibility*. It has been remarked, that rays of light—after passing through a convex lens, or medium whose surfaces are convex—converge, and are brought to a focus behind it. The whole of the rays do not, however,

meet in this focus. Those that are nearest the *axis*, R″ F of the lens, Fig. 82, are refracted to a focus more remote from the lens, than those that fall on the lens at a distance from the axis. The rays R′, R″, and R‴, are brought to a focus at F, whilst the rays R L, and R⁗, L′ converge at the point *l*, much nearer the lens. In like

Fig. 82.

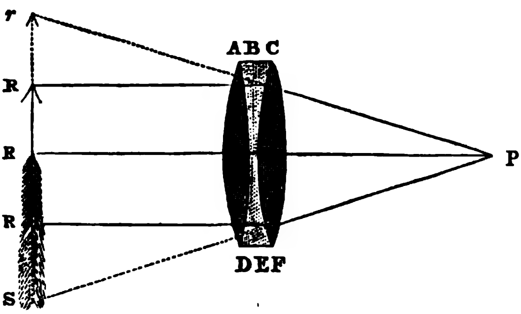


Aberration of Sphericity.

manner, rays which fall upon the lens intermediate between the rays R and R′, will have their foci intermediate between *l* and F. This diversity of focal distances is called *spherical aberration* or *aberration of sphericity:* the distance *l* F is the *longitudinal spherical aberration;* and B A the *lateral spherical aberration*, of the lens. This aberration is the source of confusion in common lenses; and as it is dependent upon the shape of the lens, it has been obviated by forming these instruments of such degrees of curvature, that the rays, falling upon the centre or margins of the lens, may be refracted to the same focus. This is effectually accomplished by lenses, whose sections are ellipses or hyperbolas. In a common lens, the inconvenience is obviated by employing lenses of a small number of degrees, or by interposing an opaque body—called, by the opticians, a *diaphragm*—anterior to the lens, so that the rays of light can only impinge upon the central part, and consequently be refracted to the same focus. This diaphragm is present in all telescopes, and occupies the situation of the curves D and D′, so as only to admit the rays R′, R″, and R‴, to fall upon the lens. Such an apparatus, we shall find, exists in the human eye.

Lastly,—it has been already observed, that the different rays, constituting the solar spectrum, are unequally refrangible,—the red being the least, the violet the most so; hence the cause of their dispersion in the spectrum. It follows from this fact, that, whenever light experiences refraction, there must be more or less dispersion of its constituent rays; and the object, seen by the refracted ray, will appear coloured. This must, of course, occur more particularly near the margins of the lens, where the surfaces become less and less parallel until they meet. The inconvenience resulting from this dispersion is called the *aberration of refrangibility* or *chromatic aberration*, and it has been attempted to be obviated by glasses, which have been termed, in consequence, *achromatic*. These are made by combining transparent bodies of different dispersive powers, in such sort, that they may compensate each other; and thus the object be seen in its proper colours, notwithstanding the refraction. Dr. Blair found, for example, that by enclosing chloride of antimony, B E, between two convex lenses of crown glass, A D and C F, the parallel rays R R, and R were refracted to a single focus at P without the slightest trace of secondary colour.

Fig. 83.



Aberration of Refrangibility.

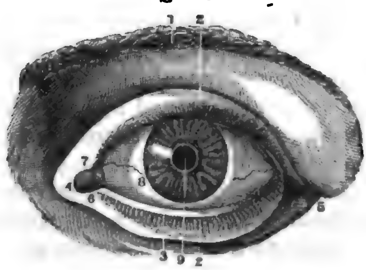
Newton was of opinion, that the light, in traversing a refracting medium, always experiences a dispersion of its rays, proportional to its refraction. He therefore believed, that it would be impossible to fabricate an achromatic glass. This is one of the rare cases in which that illustrious philosopher erred. Since his time—and chiefly by the labours of Mr. Dollond—instruments have been formed on the principles above mentioned, so as to greatly diminish the inconveniences sustained from the use of common lenses; although they may still not be perfectly *achromatic*. The inconvenience is farther obviated by the diaphragm in telescopes, already referred to. As the dispersion is most experienced near the margin of the lens, it shuts off the rays, which would otherwise fall upon that portion, and diminishes the extent of aberration. The human eye is achromatic. It is obviously essential that it should be so; and this result is owing to a combination of causes. It is formed of media of different dispersive powers. Its lens is constituted of layers of different densities, and it is provided with a diaphragm of singularly valuable construction.

Such are the prominent points of the beautiful science of optics, that chiefly concern the physiologist as an introduction to vision. Others will have to be adverted to, as we consider the eye in action.

2. ANATOMY OF THE ORGAN OF VISION.

The human eye is almost spherical, except for the prominence at its anterior and transparent part—the *cornea*. It has been compared to a telescope, and with much propriety; as many of the parts of that instrument have been added to execute special offices, which are admirably performed by the eye—the most perfect of all optical instruments. Every telescope consists, in part, of a tube, which always comprises pieces, capable of readily entering into each other. Within this cylinder are glasses or lenses, placed in succession from one extremity to the other. These are intended to refract the rays of light, and to bring them to determinate foci. Within the telescope is a kind of partition of paper or metal, having a round hole in its centre, and usually placed

Fig. 84.



Front View of the Left Eye—moderately opened.

1. Supercilia. 2. Cilia of each eyelid. 3. Inferior palpebra. 4. Internal canthus. 5. External canthus. 6. Caruncula lachrymalis. 7. Plica semilunaris. 8. Eyeball. 9. Pupil.

near a convex glass, for the purpose of diminishing the surface of the lens accessible to the rays of light, and thus of obviating spherical aberration. The interior of the tube and of the diaphragm is coloured black, to absorb the oblique rays, which are not inservient to vision; and thus to prevent them from causing confusion. This arrangement is nearly a counterpart of that which exists in the eye. The tube of the instrument is represented by three membranes in superposition,—the *sclerotic*, *choroid*, and *retina;* the last receiving the impression of light. Within, are four refracting bodies, situate one behind the other; and intended to bring the rays of light to determinate foci,—the *cornea*, *aqueous humour*, *crystalline lens*, and *vitreous humour*. Lastly, in the interior of the eye, near the anterior surface of the crystalline, is a diaphragm—the *iris*, having an aperture in its centre—the *pupil*. These different parts demand a more detailed notice.

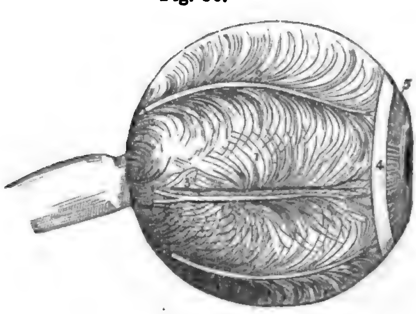
1. *Coats of the Eye.*—Before describing the coats of the eye it may be remarked, that the eyeball is invested with a membranous tunic, which separates it from the other structures of the orbit; and forms a smooth, hollow surface by which its motions are facilitated. This investment has been variously called, *cellular capsule of the eye*, *ocular capsule*, *tunica vaginalis oculi*, and *submuscular fascia.*

Fig. 85.

Side View of the same Eye, as in Fig. 84, showing that the Cilia of the Upper Lid are concave upwards, and those of the Lower Lid concave downwards. The general Convexity of the Eyeball is seen.

The *sclerotic* is the outermost proper coat. It is that which gives shape to the organ, and which constitutes the *white of the eye.* It is of a dense, resisting, fibrous nature, belonging to what M. Chaussier calls *albugineous* tissue. Behind, it is penetrated by the optic nerve; and before, the cornea is dovetailed into it. It has, by some anatomists, been considered a prolongation of the dura mater, accompanying the optic nerve; whilst the choroid has been regarded as an extension of the pia mater; and the retina of the pulp of the nerve. The sclerotic is the place of insertion for the various muscles that move the eyeball, and is manifestly intended for the protection of the internal parts of the organ.

Fig. 86.



Choroid Coat of the Eye.

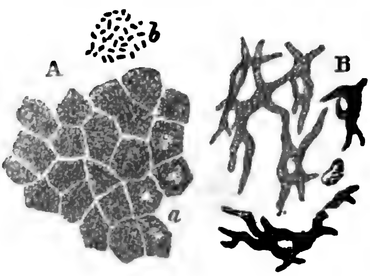
1. Curved lines marking the arrangement of venæ vorticosæ. 2, 2. Ciliary nerves. 3. A long ciliary artery and nerve. 4. Ciliary ligament. 5. Iris. 6. Pupil.

Immediately within the sclerotica, and feebly united with it by vessels, nerves, and areolar tissue,[1] is the *choroid coat;*—a soft, thin, vascular, and nervous

[1] In the situation of this areolar tissue, Arnold describes a serous membrane, *Spinnwebenhaut Arachnoidea oculi, Lamina fusca scleroticæ.*—Arnold über das Auge, Tab. iii., Fig. 2, and Weber's Hildebrandt's Handbuch der Anatomie, iv. 68, Braunschweig, 1832.

membrane. It completely lines the sclerotic; and has, consequently, the same shape and extent. Behind, it is perforated by the optic nerve; before, it has the iris united with it; and within, it is lined by the retina, which does not, however, adhere to it,—the black pigment separating them from each other. It is chiefly composed of the ciliary vessels and nerves, and consists of two distinct laminæ, to the innermost of which Ruysch—the son—gave the name *membrana Ruyschiana*. In fishes these laminæ are very perceptible, being separated from each other by a substance, which M. Cuvier considers to be glandular. The choroid is impregnated and lined by a dark-coloured mucous pigment, *stratum pigmenti, pigmentum nigrum*. In some cases, as in the *albino*, this substance, which is exhaled from the choroid, is light-coloured, approximating to white. Leopold Gmelin[1] conceives that it approaches the nature of indigo; Dr. Young,[2] regards it as a mucous substance, united to a quantity of carbonaceous matter, upon which its colour depends; and Berzelius,[3] from his chemical investigations, considers it to consist chiefly of carbon and iron; but Professor Jacob thinks it obviously an animal principle *sui generis*, its elements being oxygen, hydrogen, carbon, and nitrogen. Dr. Apjohn found 100 parts, in a dry state, leave, when incinerated, 4·46 of a calx consisting of chloride of calcium, carbonate of lime, phosphate of lime, and peroxide of iron. Mr. Thomas Wharton Jones has examined the layer of black pigment on the inner surface of the choroid microscopically. He states that it possesses organization, and constitutes a real membrane—*pigmental membrane*—consisting of very minute flat bodies of an hexagonal form, joined together at their edges.[4] It is generally considered to consist of pigment cells, which form a kind of pavement, and are somewhat of a polyhedral shape; lying in a very regular manner, with some intercellular substance between them.

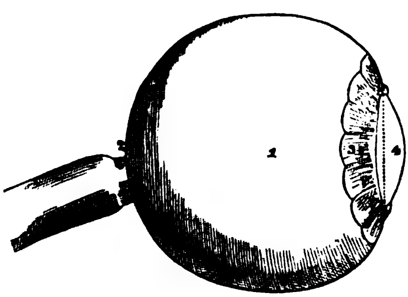
Fig. 87.



Pigmentum Nigrum.

A. Choroid epithelium, with the cells filled with pigment, except at *a*, where the nuclei are visible. The irregularity of the pigment-cells is seen. *b*. Grains of pigment.
B. Pigment-cells from the substance of the choroid. A detached nucleus is seen.—Magnified 320 diameters.

Fig. 88.



Retina.

1. Terminating anteriorly in a scalloped border. 2. Foramen of Sömmering. 3. *Zonula ciliaris*. 4. Crystalline lens.

On the outer side of the bottom of the cavity of the eye, there is

[1] Dissert. Sistens Indagationem Chemicam Pigmenti Nigri Oculorum Taurorum, Gotting., 1812.
[2] Medical Literature, p. 521, Lond., 1813. [3] Medico-Chirurg. Trans., iii. 225.
[4] Art. Eye, by Dr. Jacob, in Cyclop. of Anat. and Physiol., Part x. p. 181, for June, 1837.

a small shining space, destitute of pigment, through which the colours of the membrana Ruyschiana appear. This is termed *tapetum*. It is met with only in quadrupeds.

The *retina* is the last coat, if we except a highly delicate serous membrane — discovered by Dr. Jacob,[1] of Dublin, and called after him *Tunica Jacobi*,—which is interposed between the retina and the choroid coat.[2] It appears to be composed of cylindrical, transparent, and highly refractive bodies, which are arranged perpendicularly to the surface of the retina,—their outer extremities imbedded, to a greater or less depth, in a layer of the pigmentum nigrum. The only plausible suggestion, which, according to Messrs. Kirkes and Paget[3], has been offered, concerning the use of these bodies, is that of Brücke, who thinks it not unlikely, that they may serve to conduct back to the sensitive portion of the retina those rays of light which have traversed that membrane, and have not been entirely absorbed by the pigmentum nigrum. Mr. George H. Fielding, of Hull,[4] has affirmed, that immediately behind the retina, and in connexion with it, there is a peculiar membrane, separable into distinct layers from the choroid, and supplied with bloodvessels, which he proposes to name *membrana versicolor*. He presumes, that it receives the vibrations of light, and communicates them to the retina: the eyes, used for experiment, were those of the ox and sheep.

Fig. 89.

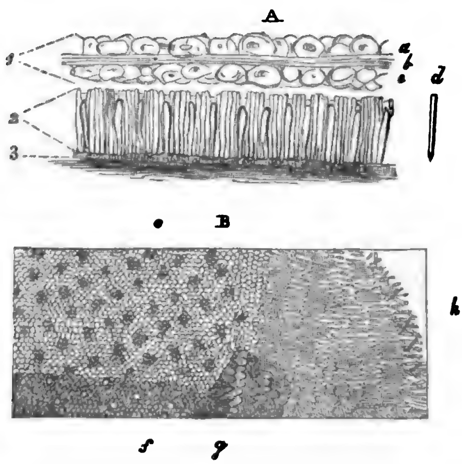


Fig. A. An Enlarged Plan of the Retina, in section.

1. The nervous structure, viz., the nerve-fibres (*b*) between nerve-cells (*a*, *c*). 2. Jacob's membrane. 3. Inner surface of choroid. *d*. One of the small pointed bodies of Jacob's membrane.

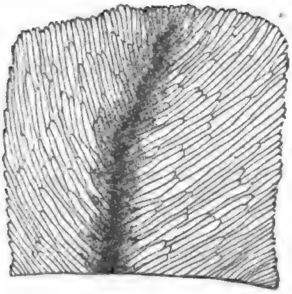
Fig. B. The Outer Surface of Jacob's Membrane. (From Hannover.)

Opposite *e*, the twin cones are obscurely seen, not being in focus, while, at the lower part of the figure, near *f*, the same bodies are clearly discernible. Towards the right side of the figure, where the objects are disturbed, the twin cones project like papillæ, at *g*, the small rods being in a great measure lost at this place. And these (small bodies) are seen to become horizontal towards the extremity of the object, *h*, where some are in disorder.

The retina lines the choroid, and is a soft, thin, pulpy, and grayish membrane, formed chiefly, if not wholly, by the final expansion of the optic nerve. M. Ribes,[5] indeed, esteems it a distinct membrane, on which the optic nerve is distributed;—a structure more consistent

[1] Philosoph. Transact. for 1819; Medico-Chirurg. Transactions, xii., Lond., 1823, and Art. Eye, in Cyclop. of Anat. and Phys., p. 186.
[2] Philosophical Transactions for 1829, p. 300.
[3] Manual of Physiology, American edition, p. 405, Philadelphia, 1849.
[4] Second Report of the British Association for the Advancement of Science; or Amer. Journal of the Med. Sciences, Nov., 1833, p. 220.
[5] Mémoir. de la Société Médicale d'Emulation, vii. 86.

Fig. 90.

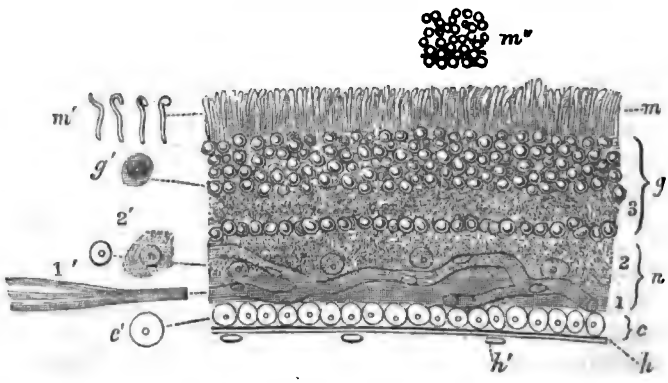


Part of the Retina of a Frog seen from the outer surface.

Magnified 300 times. (Treviranus.)

with analogy. On its inner surface it is in contact with the membrane of the vitreous humour; but they are not adherent. Anteriorly, it terminates near the anterior extremity of the choroid, forming a kind of ring, from which an extremely delicate lamina is given off. This is reflected upon the ciliary processes; dips into the intervals separating them, and, according to some anatomists, passes forward as far as the crystalline. Modern observers—Messrs. B. C. R. Langenbeck, Treviranus, Gottsche, Volkmann, E. H. Weber, Michaelis, and others, have examined minutely into the anatomy of the retina, and have shown that it consists of several layers:—Langenbeck says three; Michaelis, four. The outer layer of the true retina is considered to be formed by the optic nerve, which, at its entrance into the eye, divides into numerous small fasciculi of ultimate fibrils, that spread themselves out, and inosculate with each other by an inter-

Fig. 91.



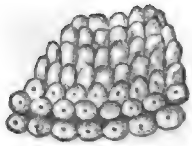
Vertical Section of the Human Retina and Hyaloid Membrane.

h. Hyaloid membrane. *h'*. Nuclei on its inner surface. *c*. Layer of transparent cells, connecting the hyaloid and retina. *c'*. Separate cell enlarged by imbibition of water. *n*. Gray nervous layer, with its capillaries. 1. Its fibrous lamina. 2. Its vesicular lamina. 1'. Shred of fibrous lamina detached. 2'. Vesicle and nucleus detached. *g*. Granular layer. 3. Light lamina frequently seen. *g'*. Detached nucleated particle of the granular layer. *m*. Jacob's membrane. *m'*. Appearance of its particles, when detached. *m''*. Its outer surface.—Magnified 320 diameters.

change of fibrils, so as to form a net-like plexus. From this plexus, the fibres of which lie in the plane of the surface of the vitreous humour, a very large number of fibrils arises in a direction perpendicular to the surface, so as to be all directed towards the centre of the eye. These pass through a delicate layer of areolar tissue, containing a minute plexus of bloodvessels, and from this every fibril receives a sheath, which envelopes its extremity, and thus forms a minute papilla. The surface of the retina, in contact with the vitreous humour, is wholly composed of these papillæ, which are closely set together. Dr.

Carpenter[1] thinks there can be little doubt that they are identical with the globules of the retina of Weber. The diameter of these globules in man, according to Weber, is from the $\frac{1}{3000}$th to $\frac{1}{3400}$th of an inch.

Fig. 92.



Papillæ of the Retina of the Frog, seen from the side turned towards the vitreous humour.

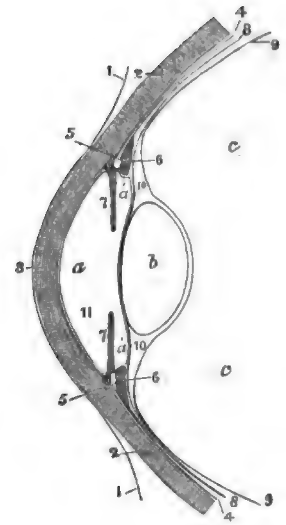
The four higher rows are seen sideways.—Magnified 300 times. (Treviranus.)

About a sixth of an inch on the outside of the optic nerve, and in the direction of the *axis* of the eye, or of a line drawn perpendicularly through the centre of the cornea, is a *yellow spot*, about a line in extent, having a depression in its centre. This spot and depression are the *limbus luteus* or *macula lutea*, and *foramen centrale* of Sömmering.[2] The yellow spot does not exist in the fœtus;[3] and the folds, described by Sömmering as surrounding the yellow spot, would appear to be a *post mortem* appearance. In the examination of two convicts, three hours after execution, the foramen was not seen satisfactorily.[4]

The retina receives many blood-vessels, which proceed from the *central artery of the retina*, or *of Zinn*. This vessel—it is important to observe — enters the eye through the centre of the optic nerve, the *porus opticus*, and, before passing directly through the vitreous humour, sends off lateral branches to the retina.

2. *Diaphanous parts of the Eye.*—The parts that act as refracting bodies, are either transparent membranes, or fluids contained in capsules, which give them a fixed shape. These parts are the *cornea*, *aqueous humour*, *crystalline*, and *vitreous humour*.

Fig. 93.



Plan of the Structures in the Fore Part of the Eye, seen in section.

1. Conjunctiva. 2. Sclerotica. 3. Cornea. 4. Choroid. 5. Annulus albidus: before this is seen the canal of Fontana. 6. Ciliary processes. 7. Iris. 8. Retina. 9. Hyaloid membrane. 10. Canal of Petit (made too large). 11. Membrane of the aqueous humour (too thick). *a*. Aqueous humour: anterior chamber and (*a*) posterior chamber. *b* Crystalline lens. *c*. Vitreous humour.

The *cornea* is the convex transparent part of the eye, advancing in front of the rest of the organ, as a watch-glass does before the case; and appearing like the segment of a smaller sphere superadded to a larger. It was, for a long time, considered to be a prolongation of the sclerotic; but they are manifestly distinct membranes, being separable by maceration. The posterior surface is concave, and, between it and the iris, is the small space occupied by the aqueous humour, called *anterior chamber of the eye*. The cornea is generally considered to be com-

[1] Human Physiology, p. 262, Lond., 1842.

[2] Sömmering, in Comment. Societ. Gotting., tom. xiii. 1795–98; A. ab Ammon, de Genesi et Usu Maculæ Luteæ, &c., Vinar., 1830.

[3] Rudolphi, Grundriss der Physiologie, B. ii. Abtheil, 1, s. 176, Berlin, 1823.

[4] W. E. Horner, Special and General Anatomy, 5th edit., p. 426, Philad., 1839, and J. Pancoast, in Wistar's Anatomy, 8th edit., Philad., 1842.

Fig. 94.

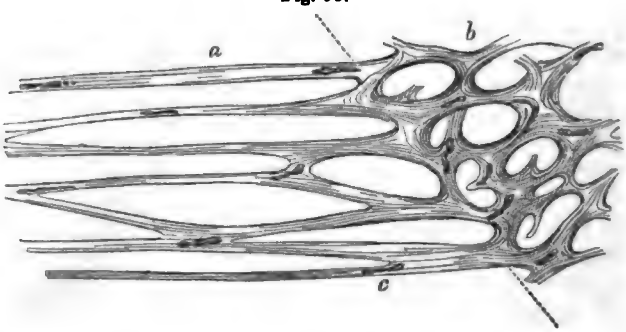
Posterior Segment of Transverse Section of the Globe of the Eye seen from within.

1. Divided edge of three tunics. The membrane covering the whole internal surface is the retina. 2. Entrance of optic nerve with arteria centralis retinæ piercing its centre. 3, 3. Ramifications of arteria centralis. 4. Foramen of Sömmering, in centre of axis of eye; the shade from sides of the section obscures the limbus luteus which surrounds it. 5. A fold of the retina, which generally obscures the foramen of Sömmering after the eye has been opened.

posed of several thin laminæ in superposition, which have been compared to horn; and hence the name of the membrane: but Mr. T. Wharton Jones[1] denies this, and describes it as consisting merely of interweaving bundles of fibres. Like corneous tissue in general, it possesses neither blood-vessels nor nerves. In animals, the density and convexity of the cornea vary with the media in which they live, and with the condition of the other refractive parts of the eye. In old age, the membrane is harder, tougher, and less transparent than in youth; and it frequently becomes completely opaque in its circumference, presenting the appearance called *arcus senilis*, — in German, Greisenbogen. Nerves have been traced into the substance of the cornea. They are ramifications of the ciliary.[2]

The *aqueous humour* is a slightly viscid fluid, which occupies the whole of the space between the posterior surface of the cornea

Fig. 95.



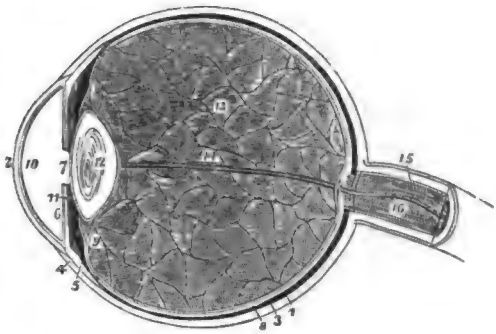
Vertical Section of the Sclerotic and Cornea, showing the continuity of their tissue between the dotted lines.

a. Cornea. *b*. Sclerotic. In the cornea, the tubular spaces are seen cut through, and in the sclerotic, the irregular areolæ. Cell-nuclei, as at *c*, are seen scattered throughout, rendered more plain by acetic acid.—Magnified 320 diameters.

and the anterior surface of the crystalline. This space is divided by the iris into two chambers—an *anterior* and a *posterior*—the latter being the small interval between the hinder surface of the iris, and the anterior surface of the crystalline. Sir David Brewster[3] erroneously asserts that the *posterior chamber* contains the crystalline and

[1] Introduction to W. Mackenzie's Practical Treatise on Diseases of the Eye, Lond., 1840.
[2] Lond. Med. Gaz., Oct., 1845, cited from Müller's Archiv.
[3] A Treatise on Optics, edit. cit., p. 241.

Fig. 96.



Longitudinal Section of the Globe of the Eye.

1. Sclerotic, thicker behind than in front. 2. Cornea, received within anterior margin of sclerotic, and connected with it by means of a bevelled edge. 3. Choroid, connected anteriorly with (4) ciliary ligament, and (5) ciliary processes. 6. Iris. 7. Pupil. 8. Third layer of eye, retina terminating anteriorly by abrupt border at commencement of ciliary processes. 9. Canal of Petit, encircles the lens (12); the thin layer in front of this canal is the zonula ciliaris, a prolongation of vascular layer of retina to the lens. 10. Anterior chamber of eye containing aqueous humour; the lining membrane, by which the humour is secreted, is represented in diagram. 11. Posterior chamber. 12. Lens, more convex behind than before, enclosed in its proper capsule. 13. Vitreous humour enclosed in hyaloid membrane, and in cells formed in its interior by that membrane. 14. Tubular sheath of hyaloid membrane, which serves for the passage of the artery of capsule of the lens. 15. Neurilemma of optic nerve. 16. Arteria centralis retinæ, embedded in the centre.

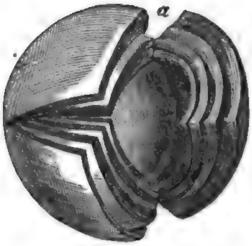
vitreous humours; and Dr. Arnott,[1] that the anterior and posterior chambers of the eye are the compartments before and behind the crystalline. Anatomists are not agreed, whether the aqueous humour have a proper membrane, which secretes it; or whether it be not an exhalation from the vessels of the iris and ciliary processes. M. Ribes derives it from the vitreous humour. Howsoever secreted, it is very rapidly regenerated when evacuated; as it must be in every operation for cataract by extraction. It is not lodged in cells; and hence readily flows out when the cornea is punctured. The quantity of aqueous humour, in the adult, is about five or six grains. Its specific gravity is not rigorously determined, but it differs slightly from that of water, being a little greater. According to Berzelius, it is composed of water, 98·10; a little albumen; chlorides and lactates, 1·15; soda, with a substance soluble in water, 0·75.

The *crystalline lens* is a small body, of a crystalline appearance, and lenticular shape,—whence its name. It measures, in the adult, about 1·33 of an inch in its greatest circumference; and is about 2½ lines thick at the centre. It is situate between the aqueous and vitreous humours; and at about one-third of the antero-posterior diameter of the organ. A depression at the anterior surface of the vitreous humour receives it; and a reflection of the proper membrane of the humour passes over it. The crystalline is surrounded by its *capsule*, the interior of which is bathed by a slightly viscid and transparent secretion, called *liquor Morgagnii*. The lens is more convex behind than before; the radius of its anterior surface being, according to Sir David Brewster,[2] 0·30; and that of its posterior surface 0·22 of an inch. It consists of a number of concentric ellipsoid laminæ, increasing in density from the circumference to the centre. Some fibres detach themselves from the different laminæ; pass to those immediately beneath, and constitute the sole bond of union that exists between them. Of old it was believed that the crystalline was of a muscular structure, and capable of

[1] Elements of Physics, &c., 2d Amer. edit., vol. ii. P. i. p. 162, Philad., 1836.
[2] Op. citat., p. 242. See, also, Philos. Transact. for 1835, p. 306.

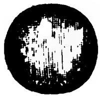
modifying its own convexity, so as to adapt the eye to different distances. This was the opinion of Des Cartes; and it has more recently

Fig. 97.



Lens, hardened in spirit and partially divided along the three interior planes, as well as into lamellæ.—Magnified 3½ diameters. (After Arnold.)

Fig. 98.



Front View of the Crystalline Humour or Lens, in the Adult.

Fig. 99.

Side View of the Adult Lens.

1. Its anterior face.
2. Its posterior face.
3, 3. Its circumference.

been received, with modifications, by Dr. Young.[1] Its muscularity is, however, by no means established, although its fibrous character is unquestionable.

The specific gravity of the human crystalline is said by Chenevix[2] to be 1·0790. He considered it to be composed chiefly of albumen. According to an analysis, however, of Berzelius,[3] it would appear to contain 35·9 parts in the hundred of a matter analogous to the colouring matter of the blood.

The *vitreous humour*, so called in consequence of its resemblance to glass, occupies the whole of the cavity of the eye behind the crystalline. It is convex behind; concave before; and is invested by a delicate, thin, transparent membrane, called *tunica hyaloidea*, which furnishes prolongations internally, that divide it into cells. It is owing to this arrangement of the membrane, and not to the density of the humour, that it has the tenacity of the white of egg. Its density does not differ materially from that of the aqueous humour;—their specific gravities being stated at 1·0009, and 1·0003 respectively. The cells, formed by the hyaloid membrane, are not all of the same shape and size. They communicate freely with each other, and are well represented in Fig. 96. At the anterior part, where the hyaloid membrane reaches the margin of the crystalline, it is separable into two laminæ; one of which is reflected over the anterior; the other over the posterior surface of the lens. Between these laminæ, and at their junction round the crystalline, a canal exists, into which air may be introduced: when it exhibits a plaited arrangement, and has been called *bullular canal of Petit;*[4] and, by the French writers, *canal godronné*, or simply *canal of Petit*. This canal is generally conceived to be devoid of aperture; but Jacobson affirms, that it has, in its sides, a number of

[1] Philos. Transact. for 1793, p. 169; and Med. Literature, p. 521, Lond., 1813.
[2] Philos. Transact. for 1803, p. 195.
[3] Medico-Chirurgical Transact., iii. 253.
[4] Mémoires de l'Académie des Sciences, Paris, 1723 and 1728; and Haller. Element. Physiol., xvi. 2, 18.

minute foramina, which admit the entrance and exit of the aqueous humour.

The composition of the vitreous humour, according to Berzelius,[1] is as follows:—Water, 98·40; albumen, 0·16; chlorides and lactates, 1·42; soda, with an animal matter, soluble only in water, 0·02. Its absolute weight is fifteen or twenty times greater than that of the aqueous humour.

8. It was remarked, in the comparison drawn between the eye and a telescope, that a diaphragm exists in the former, called *iris*, and sometimes *uvea*. Generally, however, the latter term is appropriated to the posterior lamina of the iris. By some anatomists, the iris is conceived to be a prolongation of the choroid; by others, to consist of a proper membrane, of a muscular character; and, by others, again, to be essentially vascular and nervous;—the vessels and nerves being distributed on an erectile tissue.[2] There is, in the views of anatomists and physiologists, much discrepancy regarding the structure and functions of this portion of the eye. M. Edwards,[3] of Paris, affirms, that it consists of four laminæ, two of which are extensions of laminæ, composing the choroid; a third belongs to the membrane of the aqueous humour, and is reflected over its anterior surface; the fourth is the proper tissue of the iris. M. Magendie[4] asserts, that the most recent anatomical investigations prove the iris to be muscular, and composed of two sets of fibres;—the outermost radiating, whose office is to dilate the pupil; the innermost circular and concentric, for the purpose of

Fig. 100.

Internal View of the Iris.

Fig. 101.

External View of the Iris.

contracting it. The arrangement of these fibres is represented in Fig. 100, which is an internal view of the human iris magnified three diameters; and Fig. 101, an external view, exhibiting the surface to consist essentially of a plexus of bloodvessels. Both are taken from the microscopic investigations of Mr. Bauer, and Sir Everard Home.[5] These vessels and nerves are ramifications of the ciliary,—the nerves arising from the ophthalmic ganglion and nasal branch of the fifth pair.

[1] Medico-Chirurgical Transactions, iii. 253.

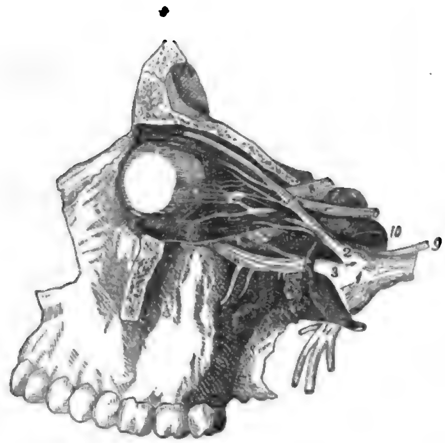
[2] Lepelletier, Physiologie Médicale et Philosophique, tom. iii. p. 158, Paris, 1832.

[3] Bullet. de la Société Philom., etc., 1814, p. 81.

[4] Op. citat., i. 61.

[5] Lectures on Comparative Anatomy, Lond., 1814–1828; and Mr. Bauer, Philosophical Transactions for 1822, p. 78.

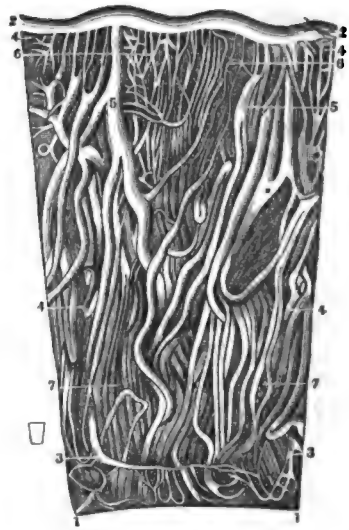
Fig. 102.



A representation of some of the Nerves of the Orbit, especially to show the Lenticular Ganglion. (Arnold.)

1. Ganglion of the fifth. 2. Ophthalmic nerve. 3. Upper maxillary. 4. Lower maxillary. 5. Nasal branch, giving the *long root* to the lenticular ganglion. 6. Third nerve. 7. Inferior oblique branch of the third connected with the ganglion by the *short root*. 8. Optic nerve. 9. Sixth nerve. 10. Sympathetic on the carotid artery.

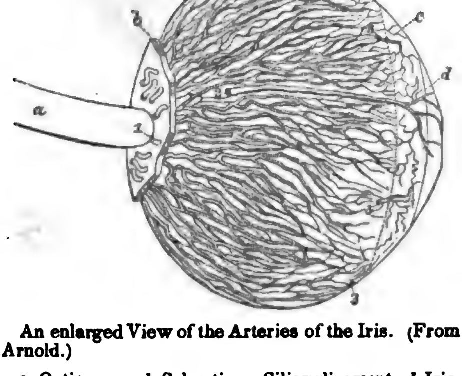
Fig. 103.



Segment of the Anterior Face of the Iris with its Vessels injected.—Magnified 25 diameters.

1, 1. Portion of the pupillary circumference of the iris. 2, 2. Part of its greater circumference surrounded by a branch of the long ciliary artery. 3. Part of the lesser circle of the iris. 4, 4. Part of its greater circle. 5, 5. Three arteries which are larger than the others, and coming from the greater circle are lost in the iris. 6. Smaller arteries arising from these. 7. Branches of the larger arteries, which are lost in the smaller circle of the iris. An outline of the natural size of this piece is seen on the left side of the figure between 3 and 7.

Fig. 104.



An enlarged View of the Arteries of the Iris. (From Arnold.)

a. Optic nerve. *b*. Sclerotic. *c*. Ciliary ligament. *d*. Iris. 1. Posterior ciliary arteries perforating the sclerotic. 2. Long (external) ciliary artery. 3. Anterior (short) ciliary arteries. (The figure is larger than natural.)

Berzelius,[1] too, affirms, that the iris has all the chemical characters of muscle.

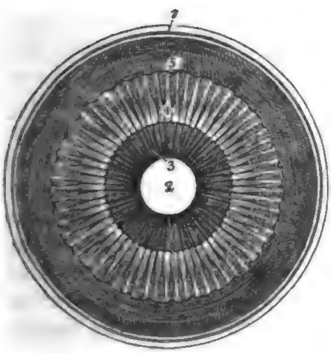
The iris is the coloured part of the eye seen through the transparent cornea; and, according to the particular colours reflected from it, the eye is said to be blue, gray, hazel, &c. In its centre is an opening, called *pupil*, through which alone the rays of light can reach the lens. This opening can be enlarged or contracted by the contraction or dilatation of the iris; and in this respect it is perpetually varying, according to circum-

[1] View of the Progress of Animal Chemistry, p. 86, Lond., 1843.

stances. In man, the pupil is circular; but it differs greatly in its dimensions and shape in different animals. On the posterior surface of the iris, the uvea, pigmentum nigrum exists, as on the choroid. This layer has likewise some effect in giving colour to the eye; in blue eyes, for instance, the tissue of the iris is nearly white,—the pigmentum which appears through it, being the chief cause of the coloration.

At the point of junction between the iris and choroid coat, they are united to the sclerotica by a band of cellular substance, called *ciliary ligament;* and, from the anterior margin of the choroid, where it unites with the base of the iris, numerous vasculo-membranous appendages arise, which appear to be prolongations of the anterior margin of the choroid, turning inwards towards the margin of the crystalline lens, and terminating abruptly, without being attached to that body. They are the *ciliary processes.* These beautiful appendages are from sixty to eighty in number; and resemble the disk of a radiated flower—*corpus ciliare.* On their posterior surface, they are covered by the same kind of pigment as that on the choroid and uvea; and they impart a stain to the membranes of the crystalline and vitreous humours. The greatest diversity of opinion, here again, exists regarding both structure and function. By some, the processes have been esteemed nervous; by others, muscular;[1] glandular; and vascular. Sir Everard Home asserts, on the authority of microscopic observations by Mr. Bauer,[2] that between the processes are bundles of muscular fibres of considerable

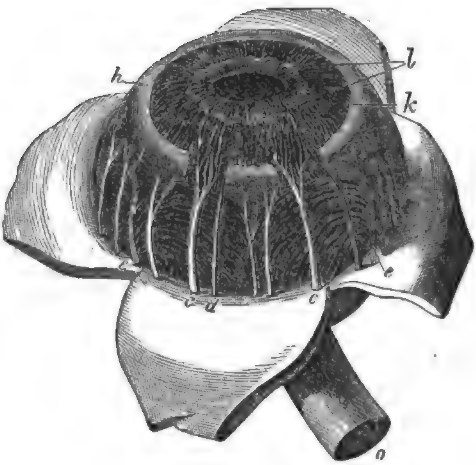
Fig. 105.



Anterior Segment of a Transverse Section of the Globe of the Eye seen from within.

1. Divided edge of the three tunics; sclerotic, choroid (the dark layer), and retina. 2. Pupil. 3. Iris, the surface presented to view in this section being the uvea. 4. Ciliary processes. 5. Scalloped anterior border of the retina.

Fig. 106.



Choroid and Iris, exposed by turning aside the Sclerotica.

c, c. Ciliary nerves branching in the iris. *d.* Smaller ciliary nerve. *e, e.* Vasa vorticosa. *h.* Ciliary ligament and muscle. *k.* Converging fibres of the greater circle of the iris. *l.* Looped and knotted form of these near the pupil, with the converging fibres of the lesser circle of the iris within them. *o.* The optic nerve. (From Zinn.)

[1] Hyrtl, Lehrbuch der Anatomie des Menschen, &c., s. 408, Prag., 1846.
[2] Op. citat., and Philosoph. Transact. for 1832, p. 78.

length, which originate all around from the capsule of the vitreous humour; pass forward over the edge of the lens; are attached firmly to its capsule, and there terminate. They are unconnected with the ciliary processes, or iris, and he conceives that their contraction will pull the lens towards the retina. The existence of unstriped muscular fibres in them is confirmed by the observations of Wagner, Todd and Bowman and others.[1]

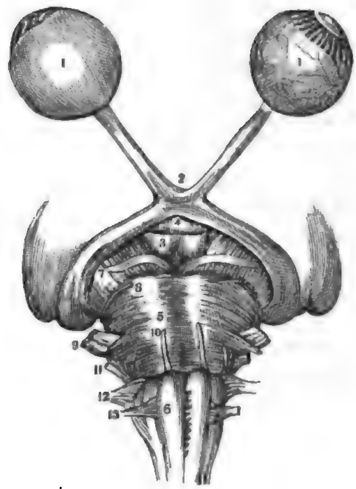
Of late, the *ciliary muscle* has been described as a grayish semitransparent ring of non-striated muscular fibres, which covers the outside of the corpus ciliare; and, by its contraction, can draw the ciliary processes forwards, and advance the lens. Dr. Clay Wallace,[2] of New York, who was one of the early describers of this muscle, and did the author the favour to demonstrate it to him, is of opinion, that its fibres when they contract compress the ciliary veins, and thus produce turgescence of the ciliary processes which occasions the movement of the lens. It appears to be the same muscle as the tensor muscle of the choroid—*tensor choroideæ*—of some anatomists.[3]

Such is an anatomical view of the physical part of the eye proper, so far as is necessary for the physiological inquirer. We have yet to consider the most important part of the organ;—that which is essentially nervous and vital in its action; and which, as we have seen, goes to constitute one of the membranes of the eyeball—the retina.

The *optic nerves—second pair* of Willis—arise from the anterior part of the *optic lobes*—corpora quadrigemina[4]—and not, as was at one time universally believed, from the *thalami nervorum opticorum*. Setting out from this point, they proceed forwards towards the thalami, to which they adhere; receiving filaments from the *corpus geniculatum externum*, an eminence a little anterior to, and on the outside of, the corpora; and from a layer of cineritious substance, situate between the point of junction of the nerve of each side and the eminentiæ mammillares—called *tuber cinereum*.[5] Proceeding forward towards the eye, the nerves approach, and form a junction at the *sella turcica*, or on the upper surface of the sphenoid bone. Anterior to this point, they diverge,—each passing through the optic foramen to the corresponding eye; piercing the sclerotic and choroid at a point about one-tenth of an inch from the axis of the eye on the side next the nose, where it has a button-like appearance; and expanding to form the whole, or a part of the retina (see page 215). When the optic nerve is regarded from the inside, after removing the retina and choroid, it appears in the form of a circular spot, perforated with small holes, from which medullary matter may be expressed. This is the *lamina cribrosa* of Albinus. M. Las-

[1] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation and Developement, p. 25, Lond., 1848.
[2] A Treatise on the Eye, p. 53, 3d edit., New York, 1841, and The Accommodation of the Eye to Distances, p. 14, New York, 1850.
[3] Ruete, in Wagner's Handwörterbuch der Physiologie, 16te Lieferung, s. 297, Braunschweig, 1847.
[4] A Pathological case illustrating this origin, by G. Kennion, M. D., is in Lond. Med. Gaz., Sept., 1838.
[5] Solly, Lond. Med. Gazette, Sept. 24, 1838.

Fig. 107.



Optic Nerves, with the origin of seven other Pairs of Nerves.

1, 1. Globe of the eye; the one on the left hand is perfect, but that on the right has the sclerotic and choroid coats removed in order to show the retina. 2. Chiasm of the optic nerves. 3. Corpora albicantia. 4. Infundibulum. 5. Pons Varolii. 6. Medulla oblongata. 7. Third pair. 8. Fourth pair. 9. Fifth pair. 10. Sixth pair. 11. Seventh pair. 12. Eighth pair. 13. Ninth pair.

saigne has examined the chemical composition of the optic nerve and retina; and concludes, from his experiments, that the retina is formed of the same elements as the cerebral and nervous substance; differing only in the proportion of constituents.

It is a question that has often been agitated, whether the optic nerves, at their junction on the sella turcica, simply lie alongside each other, or decussate so that the root of the nerve of the left eye is on the right side, and that of the right on the left. Anatomical investigations have, hitherto, left the question unsettled; and pathology appears to have furnished proofs on both sides. Thus, where the right eye has been lost for a considerable time, the optic nerve of the *same* side has been found in a state of atrophy through its whole extent. In other cases of the kind, the posterior portion of the *left* nerve has been found in this condition.[1] Fishes have the nerve arising from one side of the brain, and passing to the eye of the other side; hence crossing, but not uniting. On the other hand, Vesalius[2] gives a plate of a case in which he found the optic nerves passing to the eye of the same side from which they originate, without touching at all; and yet without disturbance of vision. It is not necessary, however, to adduce the numerous cases that have been published in favour of the one view or the other. It is impossible to sift those that are entitled to implicit confidence from those that are not. It may merely be remarked that certain observations of Valsalva, Cheselden,[3] and Petit[4] appear to show, that where the brain is injured, it is the eye of the opposite side that is affected; and, in cases of hemiplegia or paralysis of one side of the body, we certainly have many instances for testing the accuracy of this opinion. Sömmering[5]—whose correctness as an observing anatomist has never been disputed—affirms, that he had an opportunity of examining seven blind persons, in all of whom the atrophy of the nerve was on the side or root opposite to the eye affected.[6]

[1] Rudolphi, Grundriss der Physiologie, B. ii. Abth. 1, s. 203, Berlin, 1823.
[2] De Corp. Human. Fabric., lib. iv. c. 4.
[3] Anatomy of the Human Body, 13th edit., Lond., 1792.
[4] Mémoir. de l'Acad., 1723 and 1728.
[5] Blumenbach, Med. Bibl., ii. 2, s. 368; and De Decussatione Nervorum Opticorum, Mogunt., 1786.
[6] A case elucidative of this point in Lallemand, Sur Les Pertes Seminales, or in Dr. Wood's Translation in Dunglison's American Med. Library for 1839, p. 30.

Some, again, have advanced an opinion, that the decussation is partial, and concerns only the internal filaments; that the other filaments pass directly on to half the corresponding eye; so that one-half of each eye is supplied by straight fibres proceeding directly from the root of the same side; the other half by those resulting from the decussation of the internal fibres. Messrs. Wollaston,[1] Bérard, Pravaz,[2] Gall and Spurzheim, Cuvier, Serres, Vicq-d'Azyr, Caldani, Ackermann, the brothers Wenzel, G. R. Treviranus, J. Müller, Ruete,[3] and others,[4] embrace this opinion for the purpose of explaining the anomaly of vision called *hemiopia*, in which only one-half the object is seen. MM. Cuvier, Serres, and Caldani assert, that they have noticed the above arrangement in the nerves of the horse, when subjected to appropriate maceration. More recently, Mr. H. Mayo[5] has stated that the optic nerve consists in man of three tracts; the innermost of which is wholly commissural, connecting the two retinæ anteriorly, and the optic ganglia posteriorly. The middle tract decussates, and is considered by him to supply the part of the retina that lies on the inner side of each eyeball, between its anterior border and the entrance of the optic nerve. The external tract, he affirms, does not decussate, but passes on to supply the outer portion of the retina of the same side. Hence, the right optic nerve, in Mr. Mayo's view, supplies the right side of each eyeball; and the left the left. Dr. Wollaston himself was affected with hemiopia; and, in his case, the loss of vision was sometimes on one side, and sometimes on the other; and he thought, that the phenomena might be explained by partial decussation of the optic nerves; but Messrs. Solly[6] and Mayo have known instances of a like affection involving alternately the centre and circumference of the retina, and therefore not attributable to any such structural arrangement.

These views are opposed, also, by the direct experiments of M. Magendie.[7] He divided, in a rabbit, the right optic nerve, behind the point of decussation, or what has been called the *chiasm* of the nerves:—the sight of the left eye was destroyed. On cutting the left root, the sight of the right eye was equally destroyed; and on dividing the bond of union, in another rabbit, by a longitudinal incision, made between the nerves, vision was entirely abolished in both eyes;—a result, which, as he properly remarks, proves not only the existence of decussation, but also that it is total, and not partial as Wollaston had supposed. Another experiment, which he instituted, led to a similar result. Fifteen days before examining a pigeon he destroyed one eye. The nerve of the same side, as far as the chiasm, was wasted; and, behind the

[1] Philosophical Transact., 1824, p. 222.

[2] Archives Générales de Médecine, Mai. p. 59, Paris, 1825.

[3] Wagner's Handwörterbuch der Physiologie, 16te Lieferung, s. 297, Braunschweig, 1847.

[4] Hildebrandt's Handbuch der Anatomie, von E. H. Weber, Band. iii. s. 438, Braunschweig, 1832; Blumenbach, op. citat.; Sir D. Brewster's Natural Magic, Amer. edit., p. 36, New York, 1833; and Pouillet, Elémens de Physique, iii. 338, Paris, 1832.

[5] London Medical Gazette, Nov. 5, 1841.

[6] The Human Brain, its Configuration, &c., p. 263, London, 1836; and Carpenter's Human Physiology, Amer. edit., p. 246, Philada., 1843.

[7] Précis, &c., edit. cit., i. 64.

chiasm, the root of the opposite side. MM. Rolando and Flourens,[1] too, found in their experiments, that when one cerebral hemisphere was removed, the sight of the opposite eye was lost. We may conclude, then, in the present state of our knowledge, that there is not simply a junction, or what the French call *adossement*, of the optic nerves; but that they decussate at the sella turcica.[2]

The eye proper receives numerous vessels,—*ciliary arteries* and *veins*—and several nervous ramifications,—*ciliary nerves*—the greater part of which proceed from the ophthalmic ganglion of the fifth pair. The following are the dimensions, &c., of the organ, on the authority of Petit, Young, Gordon, and Brewster.

		Eng. inch.
Length of the antero-posterior diameter of the eye		0·91
Vertical chord of the cornea		0·45
Versed sine of the cornea		0·11
Horizontal chord of the cornea		0·47
Size of pupil seen through the cornea		0·27 to 0·13
Size of pupil diminished by magnifying power of cornea		0·25 to 0·12
Radius of the anterior surface of the crystalline		0·30
Radius of posterior surface		0·22
Principal focal distance of lens		1·73
Distance of the centre of the optic nerve from the *foramen centrale* of Sömmering		0·11
Distance of the iris from the cornea		0·10
Distance of the iris from the anterior surface of the crystalline		0·02
Field of vision above a horizontal line	50° } 120°	
Field of vision below a horizontal line	70° }	
Field of vision in a horizontal plane	150°[3]	
Diameter of the crystalline in a woman above fifty years of age		0·378
Diameter of the cornea		0·400
Thickness of the crystalline		0·172
Thickness of the cornea		0·042[4]

It is proper to remark, that all these measurements were necessarily taken on the dead organ, in which the parts are by no means in the same relative situation as when alive; and this is a cause why many of the phenomena of vision can never be determined with mathematical accuracy.

3. ACCESSORY ORGANS.

The visual organs being of an extremely delicate texture, it was of obvious importance, that they should be guarded against deranging influences. They are accordingly provided with numerous parts that afford them protection, and enable them to execute the functions for which they are destined. They are, in the first place, securely lodged in the bony cavities called *orbits*, which are of a conical figure, with the apices directed inwards. In the truncated apex the *foramen opticum* is situate, by which the optic nerve enters the orbit. Here are,

[1] Recherches Expérimentales sur le Système Nerveux, 2de édit., Paris, 1842.

[2] See, on this subject, Adelon, Physiologie de l'Homme, i. 402, 2de édit., Paris, 1829, and Bostock's Physiology, edit. cit., p. 709.

[3] According to Young, Philos. Transact., P. i. p. 46, Lond., 1801, the field of vision internally is 60°, externally 90°; according to Purkinje, (Rust's Magazine, B. xx. Berlin, 1825,) internally 60°, externally 100°.

[4] For the dimensions of different parts of the eye see Krause, in Meckel's Archiv für Anatomie und Physiologie für 1832; and Longet, Traité de Physiologie, ii. 41, Paris, 1850.

also, *superior orbitar* and *spheno-maxillary fissures*, through which many vessels and nerves proceed to the eye and its appendages. The base of the orbits is not directly opposite the apices, but tends outwards; so that the axes of these cavities, forming an angle of about 90° with each other, if prolonged, would meet at the sella turcica. The eye, however, is not placed in the direction of the axis of the orbit, but straight forward; and as it is nearly spherical, it is obvious that it cannot completely fill the conical cavity. In Fig. 108, muscles 9 and 13 indicate the shape of the upper and lower surfaces of the cavities;—the whole of the space between the posterior part of the orbit and the muscles, which is not occupied by the optic nerve, being occupied by an adipous, areolar tissue, on which the eye is placed as it were on a cushion. Under special morbid circumstances, this deposit becomes greatly augmented, so as to cause the eye to start from its socket,—constituting the disease called *exophthalmos*.

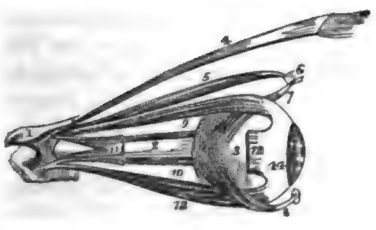
The parts, however, that are more immediately reckoned amongst the protectors of the organ—*tutamina oculi*—are the *eyebrows*, *eyelids*, and *lachrymal apparatus*. The *eyebrows* or *supercilia* are situate immediately on the *superciliary* ridge of the frontal bone. They consist of hair, varying in colour according to the individual, and turned towards the outer angle of the eye; of common integument; sebaceous follicles, situate at the root of each hair; and muscles to move them,—namely, the frontal portion of the occipito-frontalis, the upper edge of the orbicularis palpebrarum, and the corrugator supercilii. The *palpebræ* or *eyelids* are, in man, two in number, an upper and a lower, or a greater and a less,—*palpebra major* vel *superior*, and *palpebra minor* vel *inferior*,—the former covering three-fourths of the eye; hence the transverse diameter of the organ is not represented by their union,—the latter being much below it, and therefore improperly termed, by Haller, *æquator oculi*. By the separation of the eyelids, we judge, but inaccurately, of the size of the eye,—one, who is capable of separating them largely from each other, appearing to have a large eye;—and conversely.

The edge of the eyelids is thick; rounded; and furnished with hairs, which resemble generally, in colour, those of the head. These are the *eyelashes* or *cilia*. On the upper eyelid they are curved upwards; on the lower downwards. The eyelids are formed of four membranous layers in superposition; and of a fibro-cartilage, which extends along the whole edge, and keeps them tense. The outermost of these layers is the common integument, the skin of which is delicate and semitransparent, yielding readily to the motions of the eyelids, and having numerous transverse folds. The areolar tissue beneath the skin is very loose; and, under particular circumstances, is infiltrated by a serous fluid, which gives the eyelids, especially the lower, a dark appearance; but they never contain fat. Beneath the common integument is the muscular stratum, formed, in the lower eyelid, by the *orbicularis palpebrarum;* in the upper, by the same muscle, and the *levator palpebræ superioris*, (Fig. 108,) which arises from above the foramen opticum, and is inserted into the superior edge of the fibro-cartilage of the tarsus. Beneath the orbicularis palpebrarum, again, is a fibrous layer,

which occupies the whole of the eyelids, passing from the edge of the orbit to the tarsal margin, and seeming intended to limit the motion of the eyelids, when they approximate each other. The last layer, and that which forms the posterior surface of the eyelids, is a fine, delicate, transparent, mucous membrane, called *tunica conjunctiva* or *tunica adnata;* so named because it joins the eyelids to the globe of the eye. It lines, in fact, the eyelids, and is reflected over the ball; but it has been a matter of contention whether it passes over the transparent cornea. The generality of anatomists say it does; M. Ribes,[1] however, maintains the opinion, that it extends only as far as the circumference of the cornea, and that the cornea itself is covered by a proper membrane. Physiologically, this dispute is of no moment. At its outer surface, a humour is constantly exhaled, which keeps it moist, and facilitates the motions of the eyelids over the eyeball. Its loose state also favours these motions.

Both eyelids are kept tense by the aid of a fibro-cartilage, situate along the edge of each, and called *tarsus*. That of the upper is much more extensive than that of the lower; and both seem as if cut obliquely at the expense of their inner surface; so that, in the opinion of most anatomists, when the eyelids are brought together, a triangular canal

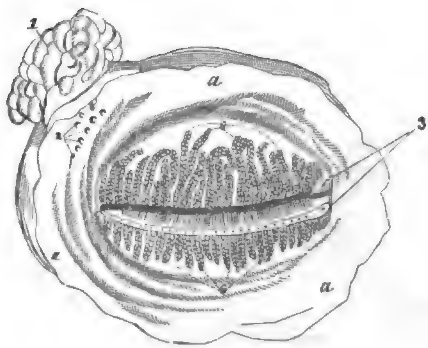
Fig. 108.



Muscles of the Eyeball.

1. A small fragment of the sphenoid bone around entrance of optic nerve into orbit. 2. Optic nerve. 3. Globe of eye. 4. Levator palpebræ muscle. 5. Superior oblique muscle. 6. Its cartilaginous pulley. 7. Its reflected tendon. 8. Inferior oblique muscle; the small square knob at its commencement is a piece of its bony origin broken off. 9. Superior rectus. 10. Internal rectus almost concealed by optic nerve. 11. Part of external rectus, showing its two heads of origin. 12. Extremity of external rectus at its insertion; the intermediate portion of muscle having been removed. 13. Inferior rectus. 14. Tunica albuginea formed by expansion of tendons of four recti.

Fig. 109.



Meibomian Glands seen from the Inner or Ocular Surface of the Eyelids, with the Lachrymal Gland—the Right Side.

a. Palpebral conjunctiva. 1. Lachrymal gland. 2. Openings of lachrymal ducts. 3. Lachrymal puncta. 6. Meibomian glands.

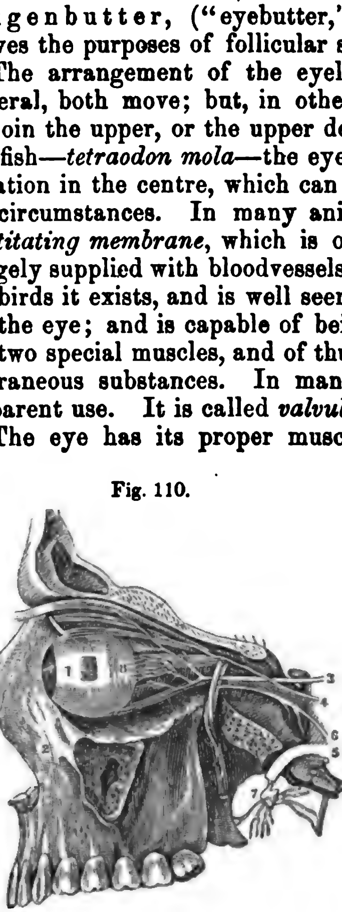
is formed between them and the ball of the eye, which has been conceived useful in conducting the tears towards the lachrymal puncta. M. Magendie[2] denies that any such canal exists; and there seems little

[1] Mémoires de la Société Médicale d'Emulation, vol. vii., Paris, 1817.
[2] Précis Elémentaire, i. 52.

evidence of it, when we examine how the tarsal cartilages come in contact. Such a canal, destined for the purposes mentioned, would seem superfluous. Besides the eyelashes, certain compound glands or follicles, called *Meibomian*, are situate in the substance of the tarsal cartilages. They are thirty or forty in number in the upper eyelid; and twenty-five or thirty in the lower, are in particular furrows between the tarsal fibro-cartilages and the conjunctiva, and secrete a sebaceous fluid, called by the French *chassie*, when in the dry state; by the Germans Augenbutter, ("eyebutter,") and by us, *gum of the eye*. It serves the purposes of follicular secretions in general.

The arrangement of the eyelids differs in different animals. In several, both move; but, in others, only one; either the lower rising to join the upper, or the upper descending to meet the lower. In the sunfish—*tetraodon mola*—the eyelid is single and circular, with a perforation in the centre, which can be contracted or enlarged, according to circumstances. In many animals there is a third eyelid, called *nictitating membrane*, which is of a more delicate texture and more largely supplied with bloodvessels; and in some animals is transparent. In birds it exists, and is well seen in the owl. It is at the inner angle of the eye; and is capable of being drawn over the ball like a curtain by two special muscles, and of thus freeing the surface of the eye from extraneous substances. In man, it is only a vestige, destined to no apparent use. It is called *valvula* or *plica semilunaris*.

Fig. 110.



View of the Third, Fourth, and Sixth Pairs of Nerves.

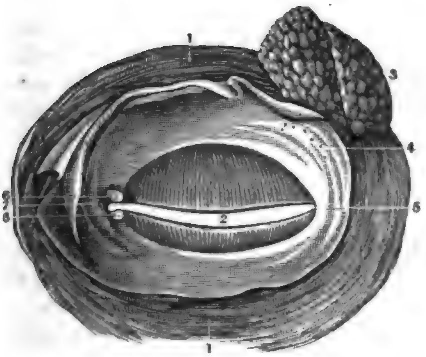
1. Ball of the eye and rectus externus muscle. 2. Superior maxilla. 3. Third pair, distributed to all the muscles of the eye except the superior oblique and external rectus. 4. Fourth pair, going to the superior oblique muscle. 5. One of the branches of the seventh pair. 6. Sixth pair, distributed to the external rectus muscle. 7. Spheno-palatine ganglion and branches. 8. Ciliary nerves from the lenticular ganglion, the short root of which is seen to connect it with the third pair.

The eye has its proper muscles, capable of moving it in various directions. Their arrangement is readily understood. They are six in number:—four *recti* or *straight muscles;* and two *oblique*. 1. *Rectus superior* or *levator*. 2. *Rectus inferior* or *depressor*. 3. *Rectus externus* or *adductor;* and 4. *Rectus externus* or *abductor*. All arise from the base of the orbit, around the optic foramen; pass forward to vanish on the sclerotica; and, according to some anatomists, extend over, and form a layer to, the cornea.

The *oblique muscles* are—1. *Greater oblique, obliquus superior, patheticus* or *trochlearis*, which arises from the inner side of the foramen opticum; passes forwards to the internal orbitar process of the frontal bone, where its tendon is reflected over a pulley or *trochlea*, and crosses the orbit to be inserted into the upper, posterior, and outer part of the globe of the eye. 2. *Lesser oblique* or *obliquus inferior*, whose fibres arise from the anterior

and inner part of the floor of the orbit, near the lachrymal groove; pass under the eyeball, and are inserted between the entrance of the optic nerve and insertion of the abductor oculi, and opposite the insertion of the obliquus superior. These muscles have their proper nerves. The *third pair—motores oculorum—*or *common oculo-muscular*, are distributed to all the muscles except the trochlearis and abductor; the *fourth pair* or *pathetic* or *internal oculo-muscular*, to the trochlearis singly; and the *sixth pair* or *external oculo-muscular*, to the abductor.

Fig. 111.



Posterior View of the Eyelids and Lachrymal Gland.

1, 1. Orbicularis palpebrarum muscle. 2. Borders of the lids. 3. Lachrymal gland. 4. Its ducts opening in the upper lid. 5. Conjunctiva covering the lids. 6. Puncta lachrymalia. 7. Lachrymal caruncle as seen from behind.

Fig. 112.

Lachrymal Canals.

1. Puncta lachrymalia. 2. Cul-de-sac at the orbital end of the canal. 3. Course of each canal to the saccus lachrymalis. 4, 5. Saccus lachrymalis. 6. Lower part of the ductus ad nasum.

The office of *tutamina oculi* is not wholly engrossed by the parts that have been mentioned. The apparatus for the secretion of the tears participates in it, by furnishing a fluid, which lubricates the surface of the eye, and keeps it in the necessary degree of humidity for the proper performance of its functions. It is a beautiful, and ingenious little apparatus; the structure of which can easily be made intelligible. It consists of the lachrymal gland; the excretory ducts of the gland; the caruncula lachrymalis; the lachrymal ducts; and the nasal duct; in other words, of two sets of parts,—one, forming the fluid and pouring it on the anterior surface of the eye; the other comprising the organs for its excretion. The *lachrymal gland* is situate in a small fossa or depression at the upper, anterior, and outer part of the orbit. It is an oval body of the size of a small almond; of a grayish colour; and composed of small, whitish, granular bodies collected into lobes. From these, six or seven excretory ducts arise, which run nearly parallel to each other, and open on the inner side of the upper eyelid, near the outer angle of the eye and the tarsal cartilage. Through these ducts, the *tears*, secreted by the lachrymal gland, are spread over the tunica conjunctiva. They are not secreted by animals that live in water.

At the inner angle of the eye is the *caruncula lachrymalis*. It is a

collection of small mucous follicles, which secrete a thick, whitish humour, to fulfil a similar office with the secretion of the Meibomian follicles. It completes the circle formed by those follicles around the eyelids. The rosy or pale colour of the body is supposed to indicate strength or debility. This it does, like other vascular parts of the system, and in a similar manner. The *puncta lachrymalia* are two small orifices, situate near the inner angle of the eye; the one in the upper; the other in the lower eyelid, at the part where the eyelids quit the globe to pass round the caruncula lachrymalis. They are continually open, and directed towards the eye. Each punctum is the commencement of a *lachrymal duct*, which passes towards the nose in the substance of the eyelids, between the orbicularis palpebrarum and tunica conjunctiva. These open, as represented in Fig. 112, into the *lachrymal sac*, which is nothing more than the commencement of the *nasal duct* or *ductus ad nasum*. The bony canal is formed by the anterior half of the os unguis, and by the superior maxillary bone, and opens into the nose behind the os spongiosum inferius. Through these excretory ducts, all of which are lined by a prolongation of mucous membrane, the tears pass into the nasal fossæ.

Dr. Horner,[1] professor of anatomy in the University of Pennsylvania, has best described a small muscle, which is evidently a part of the lachrymal apparatus, and to which he gives the name *tensor tarsi*. It is on the orbital face of the lachrymal sac; arises from the superior posterior part of the os unguis; and, after having advanced a quarter of an inch, bifurcates; one fork being inserted along each lachrymal duct, and terminating at or near the punctum. It is probable, that the function of this muscle is to keep the punctum properly directed towards the eyeball; or, as Dr. Physick suggested, to keep the lids in contact with the globe. The office, assigned to it by Dr. Horner, of enlarging, by its contraction, the cavity of the lachrymal sac, and thus producing a tendency to a vacuum—which vacuum can be more readily filled through the puncta than through the nose, owing to the valves or folds of the internal membrane of the sac—is ingenious, but apocryphal. The tensor tarsi muscle is now commonly associated with the name of Horner[2]—"muscle of Horner."

4. PHYSIOLOGY OF VISION.

The preceding anatomical sketch will enable the reader to comprehend this important organ in action. In describing the office executed by its various components, we shall follow the order there observed, premising some general considerations on the mechanism of vision; and afterwards depict the protecting and modifying influences exerted by the various accessory parts:—the different phenomena of vision will next be explained; and, lastly, the information conveyed to the mind by this sense.

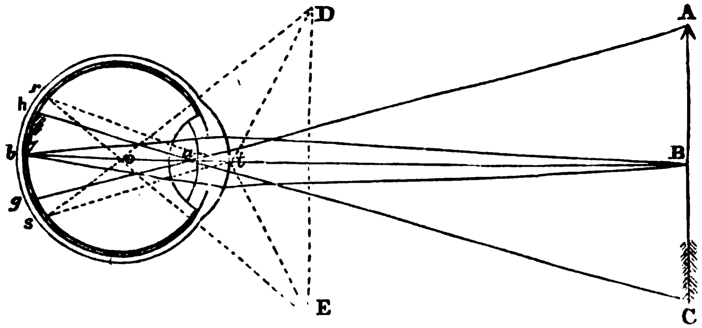
In tracing the progress of luminous rays through the purely physical

[1] Lessons in Practical Anatomy, 3d edit., p. 116, Philad., 1836; and General Anatomy and Histology, 6th edit., ii. 425, Philad., 1843. Also, Rosenmüller's Handbuch der Anatomie, dritte Auflage, Leipz., 1819.

[2] T. W. Jones, art. Lachrymal Organs, Cyclop. of Anat. and Physiol., July, 1840.

part of the organ, we shall, in the first instance, suppose a single cone to proceed from a radiant point in the direction of the axis of the eye; or, in other words, of the antero-posterior diameter of the organ, B *b*.

Fig. 113.



Progress of Luminous Rays through the Eye.

It is obvious, that the rays which fall upon the transparent cornea can alone be inservient to vision. Those that impinge upon the sclerotica are reflected; as well as a part of those that fall upon the cornea, giving occasion, in the latter case, to the image observed in the eye, and to the brilliancy of the organ. Nor does the whole of the cornea admit rays, for it is commonly more or less covered, above and below, by the free edge of the eyelids. Again: the whole of the light, that enters the cornea, does not impinge upon the retina. A portion falls upon the iris, and is reflected back to the eye, in such manner as to give us the notion of the colour of the organ. It is, consequently, the light, which passes through the pupil, that can alone attain the retina.

Some interesting points of diagnosis are connected with the reflection which takes place from the humours of the eye. If a lighted candle be held before an eye the pupil of which has been dilated by belladonna, and in which there is no obscurity in the humours or their capsules, three distinct images of the flame are perceptible—situated one behind the other. Of these images the anterior and the posterior are erect; the middle inverted. The anterior is the brightest and most distinct; the posterior the least so. The middle one is the smallest, but it is bright. The anterior erect image is produced by the cornea; the posterior by the anterior surface of the lens; and the middle or inverted image by the concave surface of the capsule of the crystalline. M. Sanson proposed this catoptric method of examining the eye as a means of diagnosis between cataract and amaurosis,—in the latter all the images being seen: and experience has shown it to be a valuable mode of investigating various conditions of the eye, which might not be readily understood without its agency.[1]

[1] Gazette Médicale de Paris, 27 Janvier, 1844. See, also, T. Wharton Jones, The Principles and Practice of Ophthalmic Medicine and Surgery, Amer. edit. by Dr. Hays, p. 39, Philad., 1847.

If we suppose a luminous cone to proceed from a radiant point B, Fig. 113, directly in the prolongation of the antero-posterior diameter of the eye, the axis of this cone will also be the axis of the organ; so that a ray of light, impinging upon the humours in the direction of the axis, as in the case of the lenses previously referred to, will pass through the humours without undergoing deflection, and will fall upon the retina at *b*. This, however, is not the case with the other rays composing the cone. They do not fall perpendicularly upon the cornea; and are, consequently, variously refracted in their passage through the cornea, aqueous humour, crystalline, and vitreous humour; but in such a manner that they join their axis in a focus at a point where it strikes the retina.

The transparent parts of the eye, as has been seen, are of different densities, and consequently possessed of different refractive powers. These powers it has been attempted to estimate; and the following is the result of the somewhat discordant evaluations of different experimenters;—the power of air being 1·000295.

	Cornea.	Aqueous Humour.	Crystalline Lens.				Vitreous Humour.
			Capsule.	Outer Layers.	Centre.	Mean.	
Hawksbee		1·33595					1·33595
Jurin		1·3333					
Rochon		1·329					1·332
Young		1·3333					
Chossat	1·339	1·338	1·339	1·338	1·393	1·384	1·339
Brewster		1·3366	1·3767		1·3990	1·3839	1·3394[1]

A ray of light impinging obliquely on the surface of the transparent cornea passes from a rarer to a denser medium. It will, consequently, be refracted towards a perpendicular raised from the point of impact. From this cause, as well as from the convexity of the cornea, it will be rendered more convergent; or, in other words, approach the axis of the cone. In proceeding through the aqueous humour, little variation will be produced, as the densities of it and the cornea differ but little; the latter is slightly more refractive, according to the table; and therefore the tendency will be to render the ray less convergent. This convergence gives occasion to the passage of a greater number of rays through the pupil; and necessarily adds to the intensity of the light that impinges on the crystalline. Pursuing the ray through the two chambers of the eye, we find it next impinging on the surface of the crystalline, which possesses a much higher refractive power than the cornea or aqueous humour; in the ratio of 1·384 to 1·336. From this cause, and from the convexity of the anterior surface of the lens, the ray is rendered still more convergent or approaches still more the axis of the cone. It is probable, however, that even here some of the light is reflected back; and goes towards the formation of the image in the

[1] For the measurements of M. Vallée, see his Théorie de l'Œil, p. 20, Paris, 1843; or Longet, Traité de Physiologie, ii. 42, Paris, 1850.

eye, and the brilliancy of the organ: other reflected rays perhaps impinge upon the pigmentum nigrum lining the posterior surface of the iris, and are absorbed by it. From the crystalline the ray emerges into a medium possessing less refractive power; and, therefore, it is deflected from the perpendicular. The shape, however, of the posterior surface of the lens so modifies the perpendiculars, as to occasion such a degree of convergence, that the oblique ray meets the axis at a focus on the retina. (See Figs. 79 and 113.) In this manner two cones are formed; one having its apex at the radiant point, and its base on the cornea—the *objective cone;*—the other having its apex on the retina, and termed the *ocular cone.*

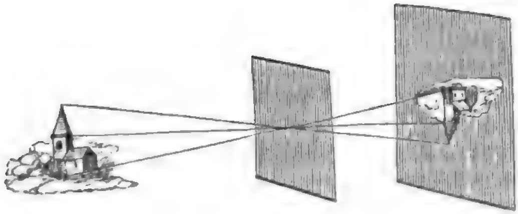
These remarks apply chiefly to the cone proceeding in the direction of the axis of the different humours, from a single radiant point. It is easy to understand, that every portion of the object A B C, Fig. 113, must be a radiant point, and project so many cones in an analogous manner, which, by impinging upon the retina, form a picture of the object upon that expansion, at *g b h*. It is important, however, to observe, that the rays proceeding from the upper part of the object fall, after refraction, upon the lower part of the retina; and those from the lower part of the object upon the upper; so that the picture or representation of the object on the retina must be inverted. How the idea of an erect object is excited in the mind will be the subject of after inquiry.

When rays, as A *g* and C *h*, fall obliquely on a lens, and pass through its centre, they suffer refraction at each of its surfaces; but as the two refractions are equal, and in opposite directions, they may be esteemed to pursue their course in a straight line. The point *a*, at which these various rays cross, is called the *optic centre* of the crystalline. Each of the straight rays proceeding from a radiant point may be assumed as the axis of all the rays proceeding obliquely from the same point; and the common focus must fall on some part of this axis. In this way the object is represented in miniature, and inverted, on the retina. As, however, the oblique ray has to pass through the cornea and aqueous humour, before it impinges on the crystalline, it undergoes considerable deflection; and consequently it is not accurate to represent it as pursuing a straight course through the different humours on its way to the retina. The main deflection—as in the case of the rays D *t s*, and E *t r*, Fig. 113—occurs at the entrance of the rays into the cornea.

That an inverted representation of external objects is formed within the eye is in accordance with sound theory; and is supported not only by indirect, but by direct experiment. If a double convex lens be fitted into an opening made in the window-shutter of a darkened chamber, luminous cones will proceed from the different objects on the outside of the house, and converge within; so that if they be received on a sheet of paper, a beautiful and distinct image of the object will be apparent. This is the well-known instrument, the *camera obscura*, of which the organ of sight may be regarded as a modification. Making abstraction, indeed, of the cornea, and of the aqueous and vitreous humours, the representation of the eye in Fig. 113, with the object,

A B C and its image on the retina, is the common camera obscura. The eye is, therefore, more complicated and more perfect than this simple

Fig. 114.



Camera Obscura.

instrument: the cornea, with the aqueous and vitreous humours, is added for the purpose of concentrating the light on the retina; the latter, in addition, affording a large space for the expansion of the retina, and preventing the organ from collapsing. In the operation for cataract by extraction, which consists in removing the lens through an opening made in the lower part of the cornea, the aqueous humour escapes, but is subsequently regenerated. If, however, too much pressure be exerted on the ball, to force the crystalline through the pupil and the opening in the cornea, the vitreous humour is sometimes pressed out, when the eye collapses, and is irretrievably lost.

Experiments have been instituted on this subject, the results of which are even more satisfactory than the facts just mentioned. These have been of different kinds. Some experimenters have formed artificial eyes of glass, to represent the cornea and crystalline, with water in place of the aqueous and vitreous humours. Another mode has been to place the eye of an ox or a sheep in a hole in the shutter of a dark chamber, having previously removed the posterior part of the sclerotica so as to permit the images of objects on the retina to be distinctly seen. Malpighi and Haller employed a more easy method. They selected the eyes of the rabbit, pigeon, puppy, &c., the choroid of which is nearly transparent; and, directing the cornea towards luminous objects, they saw them distinctly depicted on the retina. M. Magendie[1] repeated these experiments by employing the eyes of albino animals, as those of the white rabbit, white pigeon, white mouse, &c., which afford great facilities,—the sclerotica being thin, and almost transparent; the choroid, also, thin, and when the blood, which gives it colour, has disappeared after the death of the animal, offering no sensible obstacle to the passage of light. In every one of these experiments, external objects were found to be represented on the natural or artificial retina in an inverted position; the image being clearly defined, and with all the colours of the original. Yet how minute must these representations be in the living eye; and how accurate the mental appreciation,—seeing, that each impression from myriads of luminous points is transmitted by the retina to the encephalon, and perceived with unerring certainty!

[1] Précis Elémentaire, i. 70.

In the prosecution of his experiments—in some of which he was assisted by M. Biot—M. Magendie found, as might have been expected, that any alteration in the relative proportion or situation of the different humours had a manifest effect upon vision. When a minute opening was made in the transparent cornea, and a small quantity of the aqueous humour permitted to escape, the image had no longer the same distinctness. The same thing occurred when a little of the vitreous humour was discharged by a small incision made through the sclerotica. He farther found, that the size of the image on the retina was proportionate to the distance of the object from the eye. When the whole of the aqueous humour was evacuated, the image seemed to occupy a greater space on the retina, and to be less distinct and luminous; and the removal of the cornea was attended with similar results. When the crystalline was either depressed or extracted, as in the operation for cataract, the image was still formed at the bottom of the eye; but it was badly defined; slightly illuminated, and at least four times the usual size. Lastly,—when the cornea, aqueous humour, and crystalline were removed, leaving only the capsule of the crystalline and the vitreous humour, an image was no longer formed upon the retina: the light from the luminous body reached it, but it assumed no shape similar to that of the body from which it emanated.

Most of the results—as M. Magendie[1] remarks—accord well with the theory of vision. Not so, the distinctness of the image under these deranging circumstances. According to the commonly received notions on this subject, it is necessary, in order to have the object depicted with distinctness on the retina, that the eye should accommodate itself to the distance at which the object is placed. This is a subject, however, that will be discussed presently.

Such are the general considerations relating to the progress of luminous rays from an object through the dioptrical part of the organ of sight to the nervous portion—the retina. We shall now inquire into the offices executed by such of the separate parts that enter into its composition as have not already engaged attention.

We have shown, that the *cornea*, *aqueous humour*, *crystalline*, and *vitreous humour*, are a series of refractive bodies, to concentrate the luminous rays on the retina; to keep the parietes of the eye distended; and to afford surface for the expansion of the retina;—thus enlarging the field of vision. It is probably owing to their different refractive powers, that the eye is achromatic; or, in other words, that the rays, impinging upon the retina, are not decomposed into their constituent colours,—an inconvenience which appertains to the common lens (Fig. 82). The eye is strictly achromatic; and it has been an object of earnest inquiry amongst philosophers to determine how the *aberration of refrangibility* is corrected in it. Euler,[2] first perhaps, asserted, that it is owing to the different refractive powers of the humours; and he conceived, that, by imitating this structure in the fabrication of lenses,

[1] Précis Elémentaire, i. 73.

[2] Mem. Berlin, p. 279, pour 1747; and Letters of Euler, by Sir D. Brewster, Amer. edit., i. 163, New York, 1833.

they might be rendered achromatic. Experience has shown the accuracy of this opinion (Fig. 83). Others have believed, that the effect is produced by certain of the humours—as the aqueous and vitreous—which they have considered capable of correcting the dispersion produced by the cornea and crystalline. Others, again, have placed it in the crystalline, the layers of which being of different dispersive powers may correct each other. Lastly;—some have denied altogether the necessity for the eye's being achromatic; asserting, that the depth of the organ is so inconsiderable, that the dispersion of the rays, by the time they reach the retina, ought to be inappreciable. This was the opinion of M. D'Alembert. Dr. Maskelyne[1] calculated the amount of the aberration, that must necessarily take place in the eye, and concluded that it would be fourteen or fifteen times less than in a common refracting telescope; and therefore imperceptible. Uncertainty still rests on this subject; and it cannot be removed until the dispersive and refractive powers of the transparent parts of the organ as well as their exact curvatures shall have been mathematically determined. It has been already shown, that the data we possess on this subject from different observers are sufficiently imprecise.

Our knowledge, then, is restricted to the fact, that the eye is perfectly achromatic; and that, in this respect, it exceeds any instrument of human construction. The views of Euler are the most probable; and the effect doubtless is much aided by the iris or diaphragm, which prevents the rays from falling upon the margins of the lens, where, by the surfaces meeting at an angle, the aberration must necessarily be greatest.

Of the *coats of the eye*,—the *sclerotic* gives form to, and protects the organ.

The *choroid* is chiefly useful by the black pigment, which lines and penetrates it. It will be seen that some individuals, on insufficient grounds, have esteemed it the seat of vision. Leaving this question for the moment, and granting, as we shall endeavour to establish, that the impression is received upon the expansion of the optic nerve—the retina,—the use of the choroid would seem to be, in ordinary circumstances, to afford surface for the *pigmentum nigrum*, whose function it is to absorb the rays after they have passed through the retina; and thus to obviate the confusion, that would arise from varied reflections, were the choroid devoid of such dark covering. In *albinos* or white animals, in which the pigment is wanting, this inconvenience is really experienced; so that they become *nyctalopes*, or, at least, see but imperfectly during the day. In the night, or when the light is feeble, their vision is unimpaired; hence the albinos of our species have been called by the Germans and Dutch, Kakerlaken or *cockroaches*. Sir Everard Home[2] is of opinion, that the pigmentum nigrum is provided as a defence against strong light; and that, hence, it is lightest in those countries least exposed to the scorching effects of the sun. In con-

[1] Philosoph. Transactions for 1789, lxix. 256.
[2] Lectures on Comparative Anatomy, iii. 220, Lond., 1823.

firmation of this, he remarks, that it is dark in the monkey, and in all animals that look upwards, and in all birds exposed to the sun's rays; whilst the owl, that never sees the sun, has no black pigment. It doubtless possesses the function assigned to it by Sir Everard.

The use of the shining spot on the outside of the optic nerves of quadrupeds, called *tapetum*, has been an interesting theme of speculation; and has given rise to much ingenious, and to not a little ridiculous, hypothesis amongst naturalists. The absence of the black pigment necessarily occasions the reflection of a portion of the rays from the membrana Ruyschiana; and it has been presumed, that these reflected rays, in their passage back through the retina, may cause a double impression, and thus add to the intensity of vision. Another view has been, that the reflected rays may pass outwards through the retina without exciting any action, to be thrown on the object in order to increase the distinctness of the image on the retina, by an increase of its light. Dr. Fleming,[1] who usually exhibits much philosophical acumen, and physiological accuracy, thinks it not probable, that both surfaces of the retina are equally adapted for receiving impressions of external objects, and is of opinion, that the rays, in their passage inwards, alone produce the image. M. Desmoulins[2] has, however, adduced many facts and arguments to show, that the tapetum really does act the part of a mirror; and, by returning the rays through the retina, subjects it to a double contact. He affirms, that in nocturnal animals, and in many fishes and birds, which require certain advantages to compensate for the conditions of the media in which they are situate, the tapetum is of great extent, and always corresponds to the polar segment of the eyeball or to the visual axis;—that in many animals, as in the cat, the pigment is wholly wanting; and that it is only necessary for the vision of diurnal animals. He farther remarks, that, in man, it diminishes according to age, and in advanced life becomes white; and he ingeniously presumes, that this is a means employed by nature to compensate, in some measure, for the gradual diminution of the sensibility of the retina,—the choroid beneath reflecting more and more of the rays in proportion as the pigment is removed from its surface.

The views of M. Desmoulins are the most satisfactory of any that have been propounded, and they are corroborated by the experiments of Gruithuisen, Esser, and Tiedemann,[3] which show, that the luminous phenomena never occur in the eyes of nocturnal animals when light is totally excluded. Gruithuisen observed it in the dead as well as the living animal. Tiedemann perceived it in a cat, which had been decapitated for twenty hours; and it did not cease until the humours had become turbid. The views of these observers impress us the more forcibly, when we compare them with certain fanciful speculations,—as that of M. Richerand,[4] who supposes, that the use of the tapetum is to cause animals to have an exaggerated opinion of *man!* As if the

[1] Philosophy of Zoology, i. 192, Edinb., 1822.
[2] Magendie's Journal de Physiologie, iv. 89.
[3] Traité Complet de Physiologie de l'Homme, &c., traduit par A. J. L. Jourdan, p. 550.
[4] Adelon, Physiologie de l'Homme, 2de édit., i. 443. See, also, Sir E. Home's Lectures on Comp. Anat., iii. 243.

same exaggerated opinion would not be produced whatever were the object that impressed the organ.

The *iris* has been compared, more than once, to the diaphragm of a lens or telescope. Its function consequently must be,—to correct the *aberration of sphericity*, which would otherwise take place. This it does by diminishing the surface of the lens on which the rays impinge, so that they meet at the same focus on the retina. M. Biot has remarked, that this diaphragm is situate in the eye precisely at the place where it can best fulfil the office, and yet admit the greatest possible quantity of light.

The iris is capable of contracting or dilating, so as to contract or dilate the pupil. It has been already observed, that the views of anatomists regarding the muscular structure of the iris have been discrepant; and that some esteem it to be essentially vascular and nervous, the vessels and nerves being distributed on an erectile tissue. The partisans of each opinion explain the motions of the iris differently. They who admit it to consist of muscular fibres affirm, that the pupil is contracted by the action of the circular fibres, and dilated by that of the radiated. Those, again, that deny the muscularity of the organ say, that contraction of the pupil is caused by the afflux of blood into the vessels, or by a sort of turgescence similar to what occurs in erectile parts in general; and dilatation, by the withdrawal of the surplus fluid.

Admitting—and we think this must be conceded—that the iris is really muscular, we meet with the singular anomaly in its physiology—that no ordinary stimulus, applied directly to it, has any effect in exciting it to contraction. It may be pricked with the point of a cataract needle without the slightest motion being excited; and, from the experiments of Fontana[1] and Caldani,[2] it seems equally insensible when luminous rays are made to impinge upon it; yet MM. Fowler, Rinhold, and Nysten[3] have proved, that it contracts like other muscular parts on the application of the galvanic stimulus. Like them, too, it is under the nervous influence,—its movements being generally involuntary; but, there is some reason to believe, occasionally voluntary. Dr. Roget asserts, that this is the case with his own eye.[4] In the parrot, and certain nocturnal birds, its motions are manifestly influenced by volition;[5] and when the cat is roused to attention, the pupil dilates, so as to allow a greater quantity of light to reach the retina. M. Magendie[6] affirms, that the attention and effort required to see minute objects distinctly occasion contraction of the human pupil. He selected an individual whose pupil was very movable; and placing a sheet of paper in a fixed direction as regarded the eye and light he marked the state of the pupil. He then directed the person to endeavour, without moving the head or eyes, to read very minute characters traced on the paper. The pupil immediately contracted, and continued so, as long as the effort was maintained.

1 Dei Moti dell' Iride, cap. i. p. 7, Lucca, 1765.
2 Institutiones Physiologicæ, &c., Lips., 1785.
3 Magendie, Ibid., i. 75.
4 Outlines of Physiology, Amer. edit., by the Author, p. 286, Philad., 1839.
5 Mayo, Outlines of Physiology, 4th edit., p. 286, Lond., 1837.
6 Précis Elémentaire, 2de édit., i. 74.

Many experiments have been made to discover the nerve, which presides over the movements of the iris. These experiments have demonstrated, that if, instead of directing a pencil of rays upon the iris, we throw it on the retina, or through the retina on the choroid, contraction of the pupil is immediately induced. The movements of the iris must, then, be to a certain extent under the influence of the optic as an afferent nerve. It is found, indeed, that if the optic nerve be divided on a living animal, the pupil becomes immovable and expanded. Yet, that the motions of the iris are not solely influenced by this nerve is evinced by the fact, that in many cases of complete amaurosis of both eyes, there has been the freest dilatation and contraction of the pupil; and also, that section of the nerve of the fifth pair, which chiefly supplies the iris, equally induces immobility of the pupil. The same effect is produced, according to Mr. Mayo,[1] by dividing the third pair. If the trunk of that nerve be irritated, contraction of the pupil is seen to follow; and, according to Desmoulins,[2] in the eagle, whose iris is extremely movable, the third is the only nerve distributed to the organ. The general remark, made by M. Broussais[3] on the organs that combine voluntary and involuntary functions, has been considered applicable here;—that they will be found to possess both cerebral and ganglionic nerves. Accordingly, M. Magendie[4] conjectures, that those of the ciliary nerves, which proceed from the ophthalmic ganglion, preside over the dilatation of the pupil, or are the nerves of involuntary action; and that those which arise from the nasal branch of the fifth pair, preside over its contraction. We might thus understand why, in apoplexy, epilepsy, &c., the pupil should be immovably dilated. All volition and every cerebral phenomenon are abolished by the attack: the nerve of the fifth pair, therefore, loses its influence; and the iris is given up to the agency of the ganglionic nerves or nerves of involuntary action proceeding from the ophthalmic ganglion.

On the whole, our notions regarding the motions of the iris, and the nerves that preside over them, must be esteemed vague and unsatisfactory; and the obscurity is not diminished by a remark of Bellingeri.[5] The iris, he observes, derives its nerves from the ophthalmic ganglion, which is formed by the fifth in conjunction with the third pair; and its involuntary motions, he thinks, are regulated by the fifth pair. In those instances, in which the motions of the iris have been found dependent on the will, Bellingeri argues, that the ciliary nerves received no branches from the fifth—a fact, which has been proved by dissection, as well as by the circumstance, that in the parrot, owl, and the ray genus among fishes—in which the iris is under the will of the animal—there is no ophthalmic ganglion.

[1] Commentaries, P. ii. p. 5, and Outlines of Human Physiology, &c., 4th edit., p. 287, Lond., 1837.

[2] Anatom. des Systèm. Nerveux, Paris, 1825.

[3] Traité de Physiologie appliquée à la Pathologie, translated by Drs. Bell and La Roche, 3d edit., p. 77, Phil., 1833.

[4] Précis, &c., ed. cit., i. 77.

[5] Dissert. Inaugural. Turin, 1823; cited in Edinb. Med. and Surg. Journal for July, 1834.

The iris contracts or dilates according to the intensity of the light that strikes the eye. If the light from an object be feeble, the pupil is dilated to admit more of the luminous rays: on the contrary, if the light be powerful, it contracts. We see this very manifestly on opening the eyes, after they have been for some time closed, and bringing a candle suddenly near them. It is one of the means frequently employed in cerebral disease to judge of the degree of insensibility.

We shall presently inquire into the effect of contraction or dilatation of the pupil on distinct vision; and show, that they are actions for accommodating the eye to vision at different distances.

We may conclude, then, that the iris is one of the most important parts of the visual apparatus; that its functions are multiple:—that it is partly the cause of the achromatism of the organ, by preventing the rays of greatest divergence from falling near the marginal parts of the crystalline;—that it corrects the aberration of sphericity; regulates the quantity of light admitted through the pupil, and accommodates the eye, to a certain extent, to vision at different distances.

An enumeration of the multiform sentiments regarding the functions of the *ciliary processes*, will show how little we know, that is precise, on this matter also. They have often been considered contractile; some believing them connected with the motions of the iris, others to vary the distance of the crystalline from the retina. Jacobson[1] makes them dilate the apertures, which he conceives to exist in the *canal godronné*, so as to cause the admission of a portion of the aqueous humour into the canal; and thus to change the situation of the crystalline. Others believe, that they secrete the pigmentum nigrum; and others—the aqueous humour. But the processes are wanting in animals, in which the humours, notwithstanding, exist; and in our ignorance of their precise function, it has been considered that there is no opinion, perhaps, more probable than that of Haller;[2]—that they are destined to assist mechanically in the constitution of the eye; and have no farther use.

The function of the *retina* remains to be considered. It is the part that receives the impression from the luminous rays, which impression is conveyed by the optic nerve to the brain. It was, at one time, universally believed to be the most delicately sensible membrane of the frame. It has been shown by the experiments of M. Magendie,[3] that the sensibility of both it and the optic nerve is almost entirely *special*, and limited to the appreciation of light;—that the *general* sensibility is exclusively possessed by the fifth encephalic pair; and that the nerve of special sensibility is incapable of executing its functions, unless that of general sensibility is in a state of integrity. That distinguished physiologist found, when a couching needle was passed into the eye at its posterior part, that the retina might be punctured and lacerated without the animal exhibiting evidences of pain. The same result attended his experiments on the optic nerves. These nerves, both anterior and posterior to their decussation, as well as the thalami nervorum opticorum, the superficial layer of the tubercula

[1] Magendie, Précis, edit. cit., i. 78.
[2] Element. Physiol., xvi. 4, 20.
[3] Op. cit., i. 83.

quadrigemina, and the three pairs of motor nerves of the eye, gave no signs of general sensibility. On the other hand, the general sensibility of the conjunctiva is well known. It is such, that the smallest particle of even the softest substance excites intense irritation. This general sensibility M. Magendie[1] found to be totally annihilated by the division of the fifth pair of nerves within the cranium; after which, hard-pointed bodies and even liquid ammonia made no painful impression on the conjunctiva. Nictation was arrested; and the eye remained dry and fixed like an artificial eye behind the paralysed eyelids. The sight, in this case also, was almost wholly lost; but by making the eye pass rapidly from obscurity into the vivid light of the sun, the eyelids approximated; and, consequently, slight sensibility to light remained; but it was slight.

In this sense, then, as in the senses of hearing and smell, we have the distinction between a special nerve of sense, and one of general sensibility: without the latter, the former is incapable of executing its elevated functions.

The expansion of the retina occupies at least two-thirds of the circumference of the eyeball. It is of obvious importance, that it should have as much space as possible; and, in certain animals, in which the sense is very acute, the membrane is plaited so as to have a much larger surface than the interior of the eyeball; and thus to allow the same luminous ray to impinge upon more than one point of the membrane. This is seen in the eyes of the eagle and vulture, and in nocturnal animals. The inconceivable acuteness of the sense of sight in birds of prey has been already referred to under the sense of smell. It was then stated, that the strange facts regarding the condor, vulture, turkey-buzzard, &c., which meet in numbers in the forest, when an animal is killed, ought rather, perhaps, to be referred to acuteness of the sense of sight than of smell. Sir Everard Home[2] affords an additional illustration of this subject. In the year 1778, Mr. Baber, and several other gentlemen were on a hunting party in the island of Cassimbusar, in Bengal, about fifteen miles north of the city of Marshedabad: they killed a wild hog of uncommon size, and left it on the ground near the tent. An hour after, walking near the spot where it lay, the sky being perfectly clear, a dark spot in the air, at a great distance, attracted their attention; it appeared to increase in size, and move directly towards them; as it advanced it proved to be a vulture flying in a direct line to the dead hog. In an hour, seventy others came in all directions, which induced Mr. Baber to remark,—"this cannot be smell."

How inconceivably sensible to its special irritant must this membrane be in the human eye, when we consider that every part of an extensive landscape is depicted upon its minute surface; not only in its proper situation, but with all its varied tints! and how impracticable for us to comprehend, how the infinitely wider range of country can be so vividly depicted on the diminutive eye of the vulture, as to enable it to see its prey from such remote distances.

[1] Op. cit., i. 494.

[2] Lectures on Comparative Anatomy, Lond., 1814–1828.

If pressure be made on the eyeball, behind the cornea, so as to affect the retina, concentric luminous circles are seen, opposite to the part on which the pressure is applied; and, if the pressure be continued for twenty or thirty seconds, a broad undefined light, which increases in intensity every moment, rises immediately before the eye. If the eyelids be open, and light be present—on the repetition of the last experiment, a dense cloud arises, instead of the broad undefined light; and the eye becomes, in a few seconds, perfectly blind; but in the course of three or four seconds after the finger is removed, the cloud appears to roll away from before the eye. From this, it seems, that sensations of light may be produced by mechanical pressure made on the retina; in other words, the retina becomes phosphorescent by pressure. The same thing is observed if a sudden blow be given on the eye, or if we place a piece of zinc under the upper lip, and a piece of copper above the eye. A flash of light is seen; produced, doubtless, by the galvanic fluid impressing directly, or indirectly, the optic nerve. The same thing occurs in the act of sneezing, and in forcing air violently through the nostrils. On repeating the experiment of pressing the eyeball, Sir David Brewster[1] observed, that when a gentle pressure is first applied, so as to compress slightly the fine pulpy substance of the retina, a circular spot of colourless light is produced, though the eye be in total darkness, and has not been exposed to light for many hours; but if light be now admitted to the eye, the compressed part of the retina is found to be more sensible to the light than any other part; and, consequently, it appears more luminous. If the pressure be increased, beyond the point mentioned above, the circular spot of light gradually becomes darker, and, at length, black, and is surrounded with a bright ring of light. By augmenting the pressure still more, a luminous spot appears in the middle of the central dark one, and another luminous spot diametrically opposite, and beneath the point of pressure. "Considering the eye," says Sir David, "as an elastic sphere, filled with incompressible fluids, it is obvious, that a ring of fluids will rise round the point depressed by the finger; and that the eyeball will protrude all round the point of pressure; and consequently the retina, at the protruded part, will be *compressed* by the outward pressure of the contained fluid, while the retina on each side,—that is, under the point of pressure, and beyond the protruded part,—will be drawn towards the protruded part or be *dilated*. Hence the part under the finger, which was originally compressed, is now *dilated*, the adjacent parts are *compressed*, and the more remote parts, immediately without this, dilated also." "Now," continues Sir David, "we have observed, that when the eye is, under these circumstances, exposed to light, there is a bright luminous circle shading off externally and internally into total darkness. We are led therefore to the important conclusions, that when the retina is compressed in total darkness it gives out light; that when it is compressed, when exposed to light, its sensibility to light is increased; and that when it is dilated under exposure to light, it becomes absolutely blind or insensible to all luminous impressions."

[1] Letters on Natural Magic, Amer. edit., p. 27, New York, 1832.

Having traced the mode in which the general physiology of vision is effected, and the part performed by each of the constituents of the eye proper, we shall briefly consider the functions of the rest of the visual apparatus, the anatomical sketch of which has been given under the head of *accessory organs;* and afterwards inquire into the various interesting and important phenomena exhibited by this sense. These organs perform but a secondary part in vision. The *orbit* shelters the eye, and protects it from external violence. The *eyebrows* have a similar effect; and, in addition to this, the hair, with which they are furnished, by virtue of its oblique direction towards the temple, and by the sebaceous secretion that covers it, prevents the perspiration from flowing into the eye, and directs it towards the temple or root of the nose. By contracting the eyebrows, they can be thrown forwards and downwards in wrinkles; and can thus protect the eye from too strong a light, especially when coming from above.

The *eyelids* cover the eye during sleep, and preserve it from the contact of extraneous bodies. During the waking state, this protection is afforded by the instantaneous occlusion of the eyelids, on the anticipation of danger to the ball. The incessant nictation likewise spreads the lachrymal secretion over the surface of the conjunctiva, and cleanses it; whilst the movement, at the same time, probably excites the gland to augmented secretion. The chief part of the movement of nictation is performed by the upper eyelid; the difference in the action of the eyelids being estimated, by some physiologists, as four to one. Under ordinary circumstances, according to M. Adelon,[1] it is the levator palpebræ superioris, which, by its contraction or relaxation, opens or closes the eye; the orbicularis palpebrarum not acting. If the levator be contracted, the eyelid is raised and folded between the eye and orbit, and the eye is open; if, on the other hand, the levator be relaxed, or spread passively over the surface of the organ, the eye is closed. In this view, the orbicularis muscle is not contracted, except in extraordinary cases, and under the influence of volition; whilst the closure of the eye during sleep is dependent upon simple relaxation of the levator. The views of M. Broussais[2] on this subject are more satisfactory. He considers, that the open state of the eye, in the waking condition, requires no effort; because the two muscles of the eyelids are so arranged, that the action of the levator is much more powerful than that of the orbicularis; and he adduces, in proof of this, that the eyelids, at the time of death, are half open. On the other hand, the closure of the eye in sleep he conceives to be owing to the contraction of the orbicularis muscle, which acts whilst the others rest. If the opening of the eye were wholly dependent upon the action of the levator palpebræ superioris, its relaxation during insensibility and death ought to be sufficient to close the eye completely; and the orbicularis palpebrarum would be comparatively devoid of function; being only necessary for the closure of the organ under the influence of volition.

It has been found by experiments instituted by Sir Charles Bell,[3]

[1] Physiologie de l'Homme, 2de édit., i. 419, Paris, 1829. [2] Op. citat., p. 188.
[3] The Nervous System of the Human Body, Amer. edit., p. 48, Washington, 1833.

and by M. Magendie,[1] that nictation is effected under the influence chiefly of the portio dura of the seventh pair or facial nerve,—one of the respiratory nerves of Sir Charles Bell's system—the *respiratory of the face*. When this nerve is cut, nictation is completely arrested; and when the nerve of the fifth pair, also distributed to these parts, is divided, it ceases likewise, but less thoroughly; a very vivid light exciting it, but only at considerable intervals, and imperfectly. We see here something very analogous to the partition of the nerves of the senses into those possessing general, and special sensibility. Like the latter functionaries, the nerve of the seventh pair appears to be *specially* concerned in nictation, and not to be capable of executing its office, unless the fifth pair—the nerve of *general* sensibility—be in a state of integrity. The explanation of Dr. Marshall Hall is different. It has been before remarked, that if the functions of the brain be suspended or destroyed, the true spinal system being uninjured, the orbicularis palpebrarum still contracts so as to close the eyelids, when the tarsus is touched with any solid body. In this case, neither sensation nor volition can be concerned. It is a reflex action; the excitor nerves being probably branches of the fifth, and the motor, branches of the seventh pair. Hence, when the will ceases to act, as in sleep, or in apoplexy, the lids close over the eye to protect it. In the waking state, the levator palpebræ, under the influence of the will, acts as an antagonist to the orbicularis and keeps the eye open; but there is an almost irresistible tendency to close the eye; and, as in the case of respiration, the muscular contraction can only be restrained to a certain degree: it takes place, whenever the condition of the conjunctiva is such as to occasion an impression to be conveyed along the excitor nerve which demands a reflex movement to modify it; for example, when particles of dust collect upon it; or the surface becomes dry.[2]

The eyelids, by their approximation, can regulate the quantity of light that enters the pupil, when it is injuriously powerful; when feeble, they are widely separated, to allow as much light as possible to penetrate the organ. By their agency, again, the most diverging rays from an object can be prevented from falling upon the cornea; and the vision of the myopic or short-sighted can be assisted. It is a means of which they often avail themselves. The *cilia* or *eyelashes*, it is probable, are of similar advantage as regards the admission of light into the eye, and, probably, have some part in preventing extraneous bodies, borne about in the air, from reaching the sensible conjunctiva.

The *muscles* of the eyeball have acquired the chief portion of their interest in recent times, and largely through the investigations of the eminent physiologist—of whose labours we have so frequently had occasion to speak—Sir Charles Bell.[3] The arrangement of the four *straight* muscles, and especially their names, sufficiently indicate the direction in which they are capable of moving the organ, when acting singly. If any two of them contract together, the eyeball will, of

[1] Précis Elémentaire, i. 309.
[2] Carpenter, Human Physiology, p. 154, London, 1842.
[3] Op. citat., p. 102, and Anatomy and Physiology, 5th Amer. edit., ii. 213, New York, 1827.

course, be moved in the direction of the diagonal between the two forces; and if each muscle contracts rapidly after the other, the organ will execute a movement of circumduction. The *oblique* muscles are in some respects antagonists to each other, and roll the eye in opposite directions; the superior oblique directing the pupil downwards and inwards; the inferior upwards and inwards. But as the different straight muscles are capable of carrying the eye in these directions, were we to regard the two sets of muscles as possessing analogous functions, the oblique would appear to be superfluous. This, along with other reasons, attracted the attention of Sir Charles Bell to the subject; and the result of his experiments and reflections was;—that the straight muscles are concerned in the motions of the eye excited by volition: and that the oblique muscles are the organs of its involuntary motions. In this manner, he accounts for several phenomena, connected with the play of the organs in health and disease. Whilst the power of volition can be exerted over the recti muscles, the eye is moved about, in the waking state, by their agency; but, as soon as volition fails from any cause, the straight muscles cease to act, and the eye is turned up under the upper eyelid. Hence this happens at the approach of, and during sleep; and whenever insensibility occurs from any cause, as in faintness, or on the approach of dissolution; and the turning up of the eyeball, which we have been accustomed to regard as the expression of agony, is but the indication of a state of incipient or total insensibility. Whenever, too, the eyelids are closed, the eyeball is moved, so that the cornea is raised under the upper eyelid. If one eye be fixed upon an object, and the other be closed with the finger so placed as to feel the convexity of the cornea through the upper eyelid, and the open eye be shut, the cornea of the other eye will be found to be elevated. This change takes place during the most rapid winking motions of the eyelids; and is obviously inservient to the protection of the eye; to the clearing of the eyeball of everything that could obscure vision, and perhaps, as Sir Charles Bell presumes, to procure the discharge from the ducts of the lachrymal gland. During sleep, when the closure of the eye is prolonged, the transparent cornea is, by this action, turned up under the upper eyelid, where it is securely lodged and kept moist by the secretions of the lachrymal gland, follicles, and conjunctiva.

The different distributions of the motor nerves of the eye have been described in the anatomical sketch. It was there stated, that the superior oblique muscle receives one whole pair of nerves,—the fourth. This nerve, then, it seemed to Sir Charles Bell, must be concerned in the functions we have described; and, as the various involuntary motions of the eyeball are intimately concerned in expression, as in bodily pain, and in mental agony,—in which the action of the direct muscles seems, for a time, to be suspended,—he was led to consider the fourth as a nerve of expression,—a respiratory nerve; and, hence, intimately connected with the facial of the seventh pair, which, as has been already remarked, is the great nervous agent in the twinkling of the eyelids. Anatomical examination confirmed this view:—the roots of the nerve being found to arise from the same co-

lumn as other respiratory nerves. The coincidence of this twinkling, and of the motion of the eyeball upwards, was, therefore, easily understood.

There is a difficulty, however, here, which has doubtless already suggested itself to the reader. The fourth pair is distributed to the superior oblique only; the lesser oblique receives none of its ramifications. They cannot, therefore, be identically situate in this respect. Yet they are both considered by Sir Charles Bell as involuntary muscles. The action, indeed, of the lesser oblique would appear to be even more important than that of the greater oblique, as the function of the former, when acting singly, is to carry the eye upwards and inwards; and, when the action of its antagonist is abolished, this is more clearly manifested. Sir Charles found, that the effect of dividing the superior oblique was to cause the eye to roll more forcibly upwards;—in other words, it was given up, uncontrolled, to the action of the antagonist muscle. This difficulty, although it is not openly stated by Sir Charles, must have impressed him; for, after having referred to the effect of the division of the superior oblique, he is constrained to suggest an influence to the fourth pair, which would, we think, be anomalous:—that it may, on certain occasions, cause a *relaxation* of the muscle to which it goes, and, in such case, the eyeball must be rolled upwards! In addition to this, too, as Mr. Mayo[1] has observed, the distribution of the muscular nerves of the eye is not such as to allow of our opposing the straight muscles to the oblique; and one cogent reason is, that the third pair supplies part of each class.

We have still, therefore, much to learn regarding this subject, into which so much interest, and, at the same time, so much uncertainty has been infused. In some experiments on the fresh subject, made by the author with Professor Pancoast, who carefully separated the different muscles, with the view of discovering their precise action, it was clearly apparent, that the oblique muscles act in the manner above mentioned; the superior oblique directing the eye slightly inwards and downwards; and the inferior, rolling it upwards and inwards, when they acted singly: when the two were brought into action, simultaneously, they appeared to antagonize each other as rotators, but projected the eye forward. It would seem, indeed, that an important use of these muscles is to keep the eye prominent during the action of the straight muscles.

These results harmonize greatly with the deductions from experiments on living animals by Mr. Bransby Cooper.[2] He divided the superior and inferior oblique muscles on the eyes of several living rabbits; and inferred, that the oblique muscles, when acting together, suspend the eyeball in a central position in the orbitar cavity; moderate the retracting influence of the four straight muscles; and, when acting in succession, without being restricted by the influence of the straight muscles, they roll the eye on its own axis, drawing the globe forward, and at the same time tending, in a great degree, to extend the sphere of vision.

[1] Outlines of Human Physiology, 4th edit., p. 299, London, 1837.
[2] Guy's Hospital Reports, vol. iii., April and October, 1838.

The great use of the *tears* would seem to be to moisten the conjunctiva, and to remove extraneous bodies from its surface,—thus assisting the motions of the eyelids and eyeball. The tears are secreted by the lachrymal gland; and, by means of its excretory ducts, are poured upon the surface of the tunica conjunctiva, at the upper and outer part of the eyeball. Their farther course towards the puncta lachrymalia has been the subject of difference of sentiment. Many physiologists have considered that, owing to the form of the tarsal cartilages, a canal exists, when the eyelids are closed, of a triangular shape, formed anteriorly by the junction of the cartilages, and behind by the ball of the eye. M. Magendie,[1] on the other hand, denies the existence of this canal; and asserts that the tarsal cartilages do not touch by a rounded edge, but by an inner plane surface. If we were to grant the existence of this canal, it could only aid us in our explanation of the course of the tears during sleep. In the waking state, they are not ordinarily secreted in such quantity as to require that much should pass to the puncta;—the movements of nictation spreading them over the surface of the eye, whence they are partly absorbed, and the rest, perhaps, evaporated. Under extraordinary circumstances, however, the gland increases its secretion so much, that the tears not only pass freely through the lachrymal ducts into the nose, but flow over the lower eyelid. The *epiphora* or *watery eye*, caused by obstruction of these ducts, also proves that a certain quantity of the secretion must always be passing into the puncta. The physical arrangement of the eyelids and tunica conjunctiva is doubtless the cause of their course in this direction.

It has been gratuitously supposed by some, that the humour of Meibomius prevents the tears from reaching the outer surface of the lower eyelid, by acting like a layer of oil on the margin of a vessel filled with water. A similar function has been assigned to the secretion of the caruncula lachrymalis. Both these fluids, however, are probably inservient to other ends. They are readily miscible with water; become consequently dissolved in the tears, and, with the assistance of the fluid secreted by the tunica conjunctiva, aid the movements of the eyelids over the ball of the eye, and keep the tarsal margins and their appendages in the condition requisite for the due performance of their functions.

The action of the puncta themselves in admitting the tears has received different explanations. M. Adelon[2] regards it as organic and vital. We ought, however, in all cases, to have recourse to this mode of accounting for phenomena as the *ultima ratio;* and the present appears to be a case in which it is singularly unnecessary. In many of the results of absorption we are compelled to suppose, that a vital operation must have been concerned in the process. Where, for example, as in the case of the lymphatic vessels, we find the *same* fluid circulating, whatever may have been the nature of the substances whence it was obtained, the evidence, that a vital action of selection

[1] Précis, &c., edit. cit., i. 52.
[2] Physiologie, 2de édit., p. 421, Paris, 1829.

and elaboration has been going on, is irresistible; but there is no such action in the case in question. The tears in the lachrymal ducts and ductus ad nasum are identical with those spread upon the surface of the eye. This is one of the few cases in the human body, which admit of satisfactory explanation on the physical principles of capillary attraction. In vegetables, the whole of the circulation of their juices has been thus accounted for. If we twist together several threads of yarn; moisten them; and put one extremity of the roll into a vessel of water, allowing the other to hang down on the outside and to dip into an empty vessel placed below it,—we find, that the whole of the fluid in the first vessel is in a short time transferred to the second. If, again, we take a small capillary tube, less than the twentieth part of an inch in diameter, and place it so as to touch the surface of water, we find, that the water rises in it to a height, which is greater, the smaller the bore of the tube. If the diameter of the tube be the fiftieth part of an inch, the water will rise to the height of two inches and a half; if the one hundredth part of an inch, to five inches; if the two hundredth part of an inch, to ten inches; and so on. Now, the punctum lachrymale is, in our view of the subject, the open extremity of a capillary tube, which receives the fluid of the lachrymal gland and conveys it to the nose,—the punctum being properly directed towards the eyeball by the tensor tarsi muscle of Horner, and the inspiratory movements drawing it down the ductus ad nasum.

Lastly,—the *tunica conjunctiva* is another part of the guardian apparatus of the eye. It secretes a fluid, which readily mixes with the tears, and appears to have similar uses. Like mucous membranes in general, it absorbs; and, in this way, a part of the lachrymal secretion is removed from its surface. An animal, for the same reason, can be readily poisoned by applying hydrocyanic acid to it. As the conjunctiva lines the eyelids, and is reflected over the globe, it supports the friction, when the eyeball or eyelids are moved; but, being highly polished and always moist, this is insignificant.

The extreme sensibility of the outer part of the eye appertains to the tunica conjunctiva, and is dependent on the ophthalmic branch of the fifth pair. When this nerve was divided in a living animal, M. Magendie[1] found, that the membrane became entirely insensible to every kind of contact, even of substances that destroyed it chemically. In his experiments on this subject, he arrived at singular results, regarding the influence of the fifth nerve on the nutrition of the eye. When the trunk of the nerve was divided within the cranium a little after its passage over the petrous portion of the temporal bone, the cornea was found, about twenty-four hours afterwards, to become troubled; and a large spot to form upon it. In the course of from forty-eight to sixty hours, the part was completely opaque; and the conjunctiva, as well as the iris, in a state of inflammation; a turbid fluid was thrown out into the inner chamber, and false membranes proceeded from the interior surface of the iris. The crystalline and vitreous humours now began to lose their transparency; and, in the

[1] Précis Elémentaire, ii. 494.

course of a few days, were entirely opaque. Eight days after the division of the nerve, the cornea separated from the sclerotica; and the portions of the humours that remained fluid escaped at the opening. The organ diminished in size, and ultimately became a kind of tubercle, filled with a substance of a caseous appearance. M. Magendie properly concludes from these experiments, that the nutrition of the eye is under the influence of the fifth pair; and he conceives, that the opacity of the cornea was directly owing to the section of this nerve, and not to a cessation of the lachrymal secretion, or to the prolonged contact of air, caused by the paralysis of the eyelids; inasmuch as when only the branches of the nerve proceeding to the eyelids were divided, or when the lachrymal gland was taken away, the opacity did not supervene.

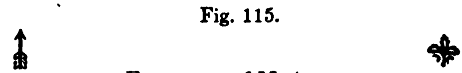
5. PHENOMENA OF VISION.

It has been more than once remarked, that the retina—the expansion of the optic nerve—is the part of the eye which receives the impressions of luminous rays, whence they are conveyed by that nerve to the brain. Yet this has been contested.

The Abbé Mariotte[1] discovered the singular fact, that when a ray of light falls, as he conceived, upon the centre of the optic nerve it excites no sensation. "Having often observed," he remarks, "on dissections of men as well as of brutes, that the optic nerve does never answer just to the middle of the bottom of the eye; that is, to the place where the picture of the object we look directly upon is made; and that in man it is somewhat higher, and on the side towards the nose; to make therefore the rays of an object to fall upon the optic nerve of my eye, and to find the consequence thereof, I made this experiment. I fastened on an obscure wall, about the height of my eye, a small round paper, to serve me for a fixed point of vision. I fastened such another on the side thereof towards my right hand, at the distance of about two feet, but somewhat lower than the first, to the end that I might strike the optic nerve of my right eye, while I kept my left shut. Then I placed myself over against the first paper, and drew back by little and little, keeping my right eye fixed and very steady on the same, and being about ten feet distant, the second paper totally disappeared."

The experiment of Mariotte can be readily repeated on the marginal representations of the *fleur-de-lis* and arrow. If we close the left eye, and direct the axis of the right eye steadily towards the arrow, when the page is held at the distance of about ten inches from the eye, the *fleur-de-lis* vanishes. The distance of the object which disappears from the eye must be about five times as great as its distance from the other object. In this case the *fleur-de-lis* and arrow are two inches asunder. It is obvious, from what has been said, regarding the axis of the orbits, and the part of the eyeball at which the optic nerve enters—that rays

Fig. 115.



Experiment of Mariotte.

[1] Philos. Transact, iii. 668, and Mémoir de l'Académie Royale des Sciences, tom. i. pp. 68, and 102.

of light from an object can never fall, at the same time, upon the insensible point of each eye. The defect in vision is, consequently, never experienced except in such experiments as those performed by Mariotte. In one of these he succeeded in directing the rays to the insensible point of both eyes at once. He put two round papers at the height of the eye, and at the distance of three feet from each other. By then placing himself opposite them, at the distance of twelve or thirteen feet, and holding his thumb before his eyes, at the distance of about eight inches, so that it concealed from the right eye the paper on the left hand, and from the left eye the paper on the right, he looked at his thumb steadily with both eyes, and both the papers were lost sight of. These experiments show, that there is a part of the retina or optic nerve, which is, in each eye, insensible to light; and that this point—*punctum cæcum*—is on the nasal side of the axis. No sooner, however, had Mariotte published an account of his experiments, than it was decided that this spot was the basis of the optic nerve; a conclusion was accordingly drawn, that the nerve is incapable of distinct vision, and this conclusion has been embraced, without examination, in many of the books on optics to the present time. Although probable, however, it is by no means certain that the light, in these cases, falls upon the base of the nerve. The direction in which the ray proceeds is such that it is reasonable to suppose it does impinge there: the suggestion of M. Tillaye,[1] that it falls upon the yellow spot of Sömmering, can only be explained by presuming him to have been in utter ignorance of the situation of the yellow spot, which, we have seen, is on the outer side of the nerve.

But, granting that the light falls at the base of the optic nerve, it by no means demonstrates, that the *nerve* is incapable of receiving the impression. It has been already shown, that the central artery of the retina penetrates the eye through the very middle of the nerve; and that through the same opening, the central vein leaves the organ. It is probable, therefore, that, in these experiments, the ray falls upon the bloodvessels, and not upon the medullary matter of the nerve; and if so, we could not expect that there should be sensation. That the insensible spot is of small magnitude is proved by the fact, that if a candle be substituted for the round paper or wafer, the candle does not disappear, but becomes a cloudy mass of light. Daniel Bernouilli[2]—it is true—considered the part of the nerve insensible to distinct impressions to occupy about the seventh part of the diameter of the eye, or about the eighth of an inch; but there must have been some error in his calculations, for the optic nerve itself can rarely equal this proportion. The estimate of Le Cat,[3] who was himself a believer in the views of Mariotte, that its size is about one-third, or one-fourth of a line, is probably still wider from the truth in the opposite direction. Simple experiment, with two wafers placed upon a door at the height of the eye, shows clearly, that both the horizontal and vertical diameters of the spot must be larger than this.[4]

[1] Adelon, Physiologie, 2de édit., i. 448, Paris, 1829.
[2] Haller, Element. Physiolog., xvi. 4, 4.
[3] Traité des Sens, p. 166, Paris, 1767; or English translation, Lond., 1750.
[4] Medical and Physiological Problems, by William Griffin, M.D., and Daniel Griffin, M.D. p. 113, Lond., 1845.

The fact, observed by Mariotte, was not suffered to remain in repose. A new hypothesis of vision was framed upon it; and, as he considered it demonstrated, that the optic nerve was insensible to light, he drew the inference, that the retina is so likewise; and as vision was effected in every part of the interior of the eye, except at the base of the optic nerve, where the choroid is alone absent, he inferred that the choroid must be the true seat of vision. The controversy, at one time maintained on this subject, has died away, and it is not our intention to disturb its ashes, farther than to remark, that De La Hire,[1] who engaged in it, entertained the opinion, that the retina receives the impression of the light in a secondary way, and through the choroid coat as an intermediate organ; and that by the light striking the choroid, the membrane is agitated, and the agitation communicated from it to the retina. The views of De La Hire are embraced by Sir David Brewster,[2] as well as by numerous other philosophers.

The opinions of Mariotte have now few supporters. The remarks already made regarding the optic nerve; the effect of disease of the retina, of the nerve itself, and of its thalami, compel us to regard its expansion as the seat of vision; and if we were even to admit, with Mariotte, that the insensible portion is really a part of the medullary matter of the nerve, and not a bloodvessel existing there, we could still satisfactorily account for the phenomenon by the anomalous circumstances in which the nervous part of the organ is there placed. The choroid coat, of great importance in the function, as well as the pigmentum nigrum, is absent; and hence we ought not to be surprised, that the function is *imperfectly* executed:—we say *imperfectly*, for the experiment with the candles exhibits, that the part is not really insensible to light, or is so in a very small portion of its surface only. It may seem at first sight, that the fact of this defect existing only in the centre of the optic nerve, or at the *porus opticus* as it has been termed, where the central artery of the retina enters, and the corresponding vein leaves the organ, militates against the idea of its being caused by the rays impinging upon these vessels; as, if so, we ought to have similar defects in every part of the retina, where the ramifications of these vessels exist. Circumstances are not here, however, identical. When the ray falls upon the porus opticus, it strikes the vessels in the direction of their length; but, in the other cases, it falls transversely upon them, pierces them, and impresses the retina beneath; so that, under ordinary circumstances, little or no difference is perceived between the parts of the retina over which the vessels creep, and others. We can, however, by an experiment of Purkinje, described by J. G. Steinbuch,[3] exhibit, that under particular circumstances such difference really does exist, and renders the bloodvessels of the organ perceptible to its own vision. If, without closing the eyelids, the left eye be covered with the hand, or some other body, and a candle or lamp be held in the right hand, within two or three inches of the right eye, but rather

[1] Mém. de l'Académie, tom. ix.

[2] Treatise on Optics, Amer. edit., by A. D. Bache, p. 243, Philad., 1833.

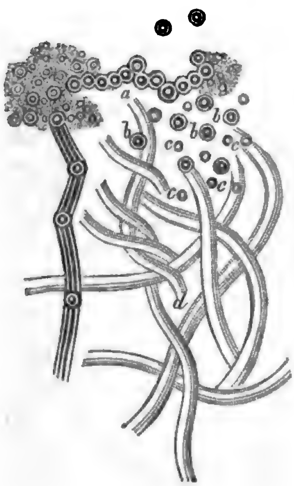
[3] Beitrag zur Physiologie der Sinne, Nürnberg, 1811. J. Müller, Elements of Physiology, by Baly, ii. 1163, Lond., 1839.

below it, (keeping the eye directed straight forward,) on moving the candle slowly from right to left, (or if the candle be held on the right side of the eye, it may be moved up and down,) a spectrum appears, after a short time, in which the bloodvessels of the retina, with their various ramifications, are distinctly seen projected, as it were, on a plane without the eye, and greatly magnified. They seem to proceed from the optic nerve, and to consist of two upper and two lower branches, which ramify towards the field of vision, where a dark spot is seen, corresponding to the foramen centrale. The origin of the vessels is a dark oval spot, with an areola. This phenomenon must be accounted for by the parts of the retina, covered by the bloodvessels, not being equally fatigued with those that are exposed.

It is by no means uncommon for appearances of cobwebs, small tubes with lateral pores, &c., to present themselves before the eyes, without changing their position when the eyes are fixed upon an object. These appearances are not owing to any modification in the humours, but are apparently dependent upon the physical condition of the retina. Some years ago, a tube of the kind mentioned, but apparently terminating in an open mouth, was the occasion of some uneasiness to the author. This is now no longer seen, but numerous opacities, somewhat resembling plexuses of vessels or nerves, are still apparent. All these appearances are usually called collectively "*muscæ volitantes.*"

They have been described by Mr. T. W. Jones[1] under three forms:—*first*, as a convoluted string of beads, or a convoluted transparent tube, containing in its interior a row of beads smaller than its diameter, except here and there where one larger than the rest is seen occupying its whole diameter—the end of the string or tube sometimes presenting a dark knobbed extremity, as if formed by an aggregation of the beads composing the string, or contained within the tube (Fig. 116, *a*); *secondly*, insulated beads, some of which—and these are more frequent, have a well-defined outline *b*;—others, and these are rarer, have a distinct outline *c*; and *thirdly*, a parcel of flexuous round watery-looking or spun-glass-like filaments with dark contours, often divided inferiorly into truncated branches, *d*.

Fig. 116.



Muscæ Volitantes.

The muscæ, which change their position, would appear to be seated in the humours of the eye; and it has been supposed in the vitreous more especially; whence the term *ento-hyaloid muscæ* given to them.

It has been remarked, that the rays, proceeding from the upper part of an object, impinge upon the lower portion of the retina; and those

[1] The Principles and Practice of Ophthalmic Medicine and Surgery, Amer. edit., p. 323, Philad., 1847.

from the lower part on the upper; hence the image of the object is reversed, as in Fig. 113. It has, accordingly, been asked;—how it is, that we see the object in its proper position, as its image is inverted on the retina? Buffon,[1] Le Cat,[2] and others believed, that, originally, we do see them so inverted; but that the sense of touch apprises us of the error, and enables us to correct it at so early a period, and so effectually, that we are afterwards not aware of the process. This cannot apply, however, to the lower animals; and, accordingly, the knot has been cut by the supposition—and there is much to favour it—that in them it is innate or intuitive.[3] Berkeley,[4] again, asserted, that the position of objects is always judged of, by comparing them with our own; and that, as we see ourselves inverted,—and this view is embraced by Müller, Volkmann,[5] and numerous others,—external bodies are in the same relation to us as if they were erect. It is not necessary to reply at length to these views. Cases enough have occurred of the blind from birth having been restored to sight to show, that no such inversion, as that described by Buffon, takes place; and the boy, who stoops down, and looks at objects between his legs, although he may be, at first, a little confused, from the usual position of the images on the retina being reversed, soon sees as well in that way as in any other. The great error with all these speculatists has been, that they have imagined a true picture to be formed on the retina, which is regarded by the mind, and therefore *seen* inverted. It need hardly be said, that there is no interior eye to take cognizance of this image; but that the mind accurately refers the impression, made upon the retina, to the object producing it; and if the lower part of the retina be impressed by a ray from the upper part of an object, this impression is conveyed by the retina to the brain as it receives it, and no error can be indulged. Professor Alison[6] offers an explanation, first suggested to him by Mr. Dick, veterinary surgeon, which turns on the alleged fact, that the course of the optic nerves and tractus optici is such, that impressions on the upper part of the retina are, in fact, impressions on the lower part of the optic lobes,—that impressions on the outer part of the former are on the inner part of the latter,—and conversely.

When a cone of light proceeds from a radiant point, as from B, Fig. 113, the whole of the rays,—whatever may be their relative obliquity,—are, as has been seen, converged to a focus upon the retina at *b*, yet the point B is seen only in one direction, in that of the central ray or axis of the cone B *b*. If we look over the top of a card at the point B, till the edge of the card is just about to hide it; or if, in other words, we obstruct all the rays that pass through the pupil, excepting the uppermost, the point is still seen in the same direction as when it was viewed by the whole cone proceeding from B. If we look, again, beneath the card, in a similar manner, so as to see the object by the low-

[1] Mémoires de l'Académie, 1743, p. 231. [2] Op. citat.
[3] Carpenter, Human Physiology, p. 266, Lond., 1842.
[4] Essay on Vision, 2d edit., p. 60, Dublin, 1709.
[5] Wagner's Handwörterbuch der Physiologie, 14te Lieferung, s. 342, Braunschweig, 1846.
[6] On Single and Correct Vision, by means of Double and Inverted Images on the Retinæ, in Transact. of the Royal Society of Edinburgh, vol. xiii., Edinb., 1836.

est ray of the cone, the radiant point will be equally seen in the same direction. Hence, says Sir David Brewster,[1] it is manifest, that the line of visible direction does not depend on the direction of the ray, but is always perpendicular to the retina; and, as the surface of the retina is a portion of a sphere, those perpendiculars must all pass through one point, "which may be called the *centre of visible direction;* because every point of a visible object will be seen in the direction of a line drawn from this centre to the visible point."

The point *o*, Fig. 113, is, in Sir David's view, the centre of visible direction. Where a luminous cone proceeds in the direction of the axis of the eye, the centre of visible direction will fall in that line, and a perpendicular, drawn from the point *b*, where the rays of the cone meet at a focus on the retina, will pass through this centre of visible direction *o*, and the same thing, he conceives, will apply to every other pencil of rays. Thus, the rays from D and E, which fall upon the cornea at *t*, will be refracted so as to impinge upon the retina at *s* and *r* respectively; and D and R will be seen in the direction of lines drawn from these points to the centre of visible direction, *o*.

This "law of visible direction" removes at once, Sir David Brewster thinks, every difficulty that besets the subject of the cause of erect vision from an inverted image on the retina. The lines of visible direction necessarily cross each other at the centre of visible direction, so that those from the lower part of the image go to the upper part of the object; and those from the upper part of the image to the lower part of the object.

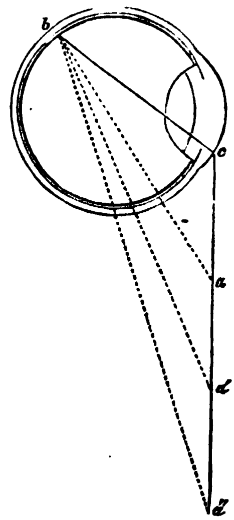
The views of Sir David are embraced by Mr. Mayo,[2] who considers them confirmed by the fact—to which reference has already been made—that any pressure made upon the retina through the eyeball causes a spectrum to be seen in a direction *opposite* to the point compressed; as well as by the following experiments of Scheiner, by whom this law of visual direction was first shown. If the head of a pin, strongly illuminated, be viewed with one eye at a distance of four inches, that is, within the common limit of distinct vision, the object is seen large and imperfectly defined,—the outermost cones of rays, which enter the pupil from each point, being too divergent to be collected to a focus on the retina. If a card pierced with a pinhole be now interposed between the eye and the object, the latter may be seen distinctly defined through the pinhole by means of rays that have entered the pupil nearly parallel, with a slightly divergent tendency. But the object may be seen by rays passing either through the upper or lower part, the right or left side, or the centre of the pupil. On shifting the card for this purpose the object appears to move in an *opposite direction.*—Or, if three pinholes be made, one in the centre, and one at either side, the object appears tripled; and if one of the side holes be closed, the *opposite* of the three objects disappears: if, for example, the left-hand pinhole be closed, the right object disappears.—Again, if the head of a pin, strongly illuminated, be viewed at the distance of

[1] Op. citat., p. 246.
[2] Outlines of Human Physiology, 3d edit., p. 277.

eighteen inches, its outline is distinct and clear; the rays passing from each point of the object, are brought to a point on the retina, but they reach the retina at different angles; and, by interposing a card perforated with a single pinhole, the object may be seen by rays, which enter the upper part, or the lower part, or the centre of the pupil. No change, however, in the visual place of the object occurs in this instance, as the card is being shifted; nor is the image multiplied when seen through several pinholes in the card.

The last experiment, says Mr. Mayo, proves, that the angle at which rays of light fall upon the retina does not affect our notion of the place of objects; and, taken with the preceding, establishes as an inductive law, that *the retina is so constituted, that, however exerted, each point of it sees in one direction only*, that direction being a line vertical to it; or that in every instance of vision, *each point of an object is seen in the direction of a line vertical to the point of the retina upon which the rays proceeding from it are collected.* It would seem, however, to be a forcible objection to this view of the subject; that all the objects, a, a' and a'' on the line ca'', Fig. 117, must fall upon exactly the same point of the cornea; and, therefore, upon the same point of the retina; yet, as only one of these lines $b\ a$ is perpendicular to the point of the retina on which the rays are collected, such a perpendicular would obviously refer the position of the object a alone correctly. Moreover, accurate examination would appear to show, that this law of visible direction cannot be optically correct, as the lines of direction cross each other at a point much anterior to the centre of the eyeball. This may be proved by making a diagram of the eye on a large scale, and laying down the course of the rays entering the organ, according to the curvatures, and refractive powers of its different parts. In this manner, Volkmann[1] found, that the lines of direction cross each other at a point a little behind the crystalline, and that they will thus fall at such different angles on different points of the retina, that no general law can be deduced respecting them.

Fig. 117.



Lines of Visible Direction.

A certain intensity of light is necessary, in order that the retina may be duly impressed, and this varies in different animals; some of which, as we have seen, are capable of exercising the function of vision in the night, and have hence been termed *nocturnal*. In man, the degree of light necessary for distinct vision varies according to the previous state of the organ. A person, passing from a brilliantly illuminated room into the dark, is, for a time, incapable of seeing any thing; but this effect differs in individuals; some being much more able

[1] Neue Beiträge zur Physiologie des Gesichtsinnes, Leipzig, 1836, and Müller's Elements of Physiology by Baly, p. 1170, Lond., 1839. See, on this subject, Medical and Physiological Problems, &c., by N. Griffin, M.D., and Daniel Griffin, M.D., p. 97, Lond., 1845.

to see distinctly in obscurity than others. This is owing to the retina being more sensible; and, consequently, requiring a less degree of light to impress it. On the other hand, a very powerful light injures the retina, and deprives it, for a time, of its function; hence the unpleasant impression produced by the introduction of lights into a room, where the company have been previously sitting in comparative obscurity; or by looking at the sun. The effect upon the retina, thus induced, is called *dazzling*. If the light that falls upon the eye is extremely feeble, and we look long and intensely upon any minute object, the retina is fatigued; the sensibility of its central portion becomes exhausted, or it is painfully agitated; and the objects appear and disappear, according as it has recovered or lost its sensibility; a kind of remission seeming to take place in the reception of the impressions.

These affections are considered by Sir David Brewster[1] as the source of many optical deceptions, which have been ascribed to a supernatural origin. "In a dark night, where objects are feebly illuminated, their disappearance and reappearance must seem very extraordinary to a person whose fear or curiosity calls forth all his powers of observation. This defect of the eye must have been often noticed by the sportsman, in attempting to mark, upon the monotonous heaths, the particular spots where moor-game had alighted. Availing himself of the slightest difference of tint in the adjacent heaths, he endeavours to keep his eye steadily upon it as he advances; but, whenever the contrast of illumination is feeble, he almost always loses sight of his mark, or if the retina does take it up a second time, it is only to lose it again."

In all the cases, in which the eye has been so long directed to a minute object that the retina has become fatigued, on turning the axis slightly away from the object, the light from it will fall upon a neighbouring part of the retina, and the object be again perceived; and in the mean time the part, previously in action, will have recovered from its fatigue. By the fact of the retina becoming fatigued by regarding an object for a long time we explain many interesting phenomena of vision. If the eye be directed, for a time, to a white wafer laid upon a black ground; and afterwards to a sheet of white paper, it will seem to have a black spot upon it, of the same size as the wafer;—the retina having become fatigued by looking at the white wafer. On the other hand, if the eye be turned to a black wafer, placed upon a sheet of white paper; and afterwards to another part of the sheet, a portion of the paper, of the size of the wafer, will seem strongly illuminated;—the ordinary degree of light appearing intense, when compared with the previous deficiency. It is on this, that the whole theory of *accidental colours*, as they are called, rests. When the eye has been for some time regarding a particular colour, the retina becomes insensible to this colour; and if, afterwards, it be turned to a sheet of white paper, the paper will not seem to be white, but will be of the colour that arises from the union of all the rays of the solar spectrum, except the one to which the retina has become insensible. Thus, if it be directed for some time to a *red* wafer, the sheet of paper will seem to

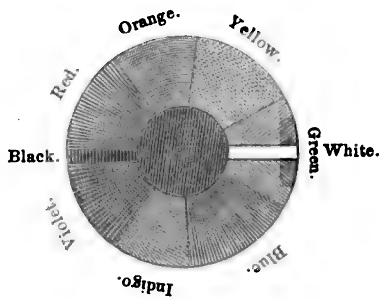
[1] Op. citat., p. 250.

be of a *bluish-green*, in a circular spot of the same dimensions as the wafer. This bluish-green image is called an *ocular spectrum*, because it is impressed upon the eye, and may be retained for a short time; and the colour *bluish-green* is said to be the *accidental colour* of the *red*. If this experiment be made with wafers of different colours, other accidental colours will be observed, varying with the colour of the wafer employed, as in the following table:—

Colour of the Wafer.	Accidental Colour, or Colour of the Ocular Spectrum.
Red,	Bluish-green.
Orange,	Blue.
Yellow,	Indigo.
Green,	Violet, with a little red.
Blue,	Orange-red.
Indigo,	Orange-yellow.
Violet,	Yellow-green.
Black,	White.
White,	Black.

If all the colours of the spectrum be ranged in a circle, in the proportions they hold in the spectrum itself, as in Fig. 118,—the accidental colour of any particular colour will be found directly opposite. Hence the two have been termed *opposite colours*.

Fig. 118.



Accidental Colours.

It will follow, from what has been said, that if the primary colour, or that to which the eye has been first directed, be added to the accidental colour, the result must be the same impression as that produced by the union of all the rays of the spectrum—of *white* light. The accidental colour, in other words, is what the primitive colour requires to make it white light. The primitive and accidental colours are, therefore, *complements* of each other; and hence accidental colours have been called *complementary colours*. They have likewise been termed *harmonic*, because the primitive and its accidental colour *harmonize* with each other in painting. It has been supposed, that the formation of these ocular spectra has frequently given rise to a belief in supernatural appearances,—the retina, in certain diseased states of the nervous system, being more than usually disposed to retain the impressions, so that the spectrum remains visible for a long time after the cause has been removed. Such appears to be the view of Drs. Ferriar,[1] Hibbert,[2] and Alderson,[3]—the chief writers in modern times, on apparitions. This subject may be the theme of future discussion. It will be sufficient, at present, to remark, that the great seat and origin of

[1] An Essay towards a Theory of Apparitions, Lond., 1813.
[2] Sketches of the Philosophy of Apparitions, Edinb., 1825.
[3] An Essay on Apparitions, &c., Lond., 1823.

spectral illusions is the brain, and that the retina is no farther concerned than it is in dreaming or in the hallucinations of insanity.

The retina is able to receive visual impressions over its whole surface, but not with equal distinctness or accuracy. When we regard an extensive prospect, that part of it alone is seen sharply, which falls upon the central part, or in the direction of the axis of the eye: we always, therefore, in our examination of minute objects, endeavour to cause the rays from them to impress this part of the retina;—the distinctness of the impression diminishing directly as the distance from the central foramen increases. This central point, called the *point of distinct vision*, is readily discriminated on looking at a printed page. It will be found, that although the whole page is represented on the retina, the letter to which the axis of the eye is directed is alone sharply and distinctly seen; and, accordingly, the axis of the eye is directed in succession to each letter as we read. In making some experiments on indistinctness of vision at a distance from the axis of the eye, Sir David Brewster[1] observed a singular peculiarity of oblique vision, namely,—that when we shut one eye and direct the other to any fixed point, such as the head of a pin, and hence see all other objects within the sphere of vision indistinctly, if one of these objects be a strip of white paper, or a pin lying upon a green cloth, after a short time, the strip of paper or the pin will altogether disappear, as if it were entirely removed, the impression of the green cloth upon the surrounding parts of the eye extending itself over the part of the retina, which the image of the pin occupied. In a short time, the vanished image will re-appear, and again vanish. When the object seen obliquely is luminous, as a candle, it never vanishes entirely, unless its light is much weakened by being placed at a great distance; but it swells and contracts, and is encircled with a nebulous halo,—the luminous impressions extending themselves to adjacent parts of the retina not directly influenced by the light itself.

From these, and other experiments of a similar character, Sir David infers, that oblique or indirect vision is inferior to direct vision, not only in distinctness, but from its inability to preserve a sustained vision of objects. Yet it is a singular fact, that *indirect* has a superiority over *direct* vision in the case of minute objects, such as small stars, which cannot, indeed, be seen by the latter. A mode frequently adopted by astronomers for obtaining a view of a star of the last degree of faintness is to direct the eye to another part of the field, and in this way, a faint star, in the neighbourhood of a large one, often becomes very conspicuous, so as to bear a certain illumination, and yet it entirely disappears, as if suddenly blotted out, when the eye is turned full upon it; and, in this way, it can be made to appear and disappear as often as the observer pleases. Sir J. F. W. Herschel, and Sir James South, who describe this method of observation, attempt to account for the phenomenon by supposing, that the lateral portions of the retina, being less fatigued by strong light, and less exhausted by perpetual attention, are probably more sensible to faint impressions

[1] Op. citat., p. 248.

than the central ones; and the suggestion carries with it an air of verisimilitude. Sir David Brewster, however,—from the result developed by his experiments, that, "in the case of indirect vision, a luminous object does not vanish, but is seen indistinctly, and produces an enlarged image on the retina, besides that which is produced by the defect of convergency in the pencils,"—concludes somewhat mystically, "that a star, seen indirectly, will affect a large portion of the retina from these two causes, and, losing its sharpness, will be more distinct."[1]

In order that the image of any object may impress the retina, and be perceived by the mind, it must, first of all, occupy a space on the retina sufficiently large for its various parts to be appreciated: in the next place, the image must be distinct or sharp,—in other words, the luminous rays that form it must converge accurately to a focus on the retina: and lastly, the image must be sufficiently illuminated. Each of these conditions varies with the size of the body, and the distance at which it is from the eye; and there are cases, where they are all wanting, and the object is consequently invisible. An object may be so small, that the eye cannot distinguish it, because the image, formed on the retina, is too minute. To remedy this inconvenience, the object must be brought near to the eye, which increases the divergence of the rays and the size of the image; but if we approach it too close to the eye, the rays are not all brought to a focus on the retina, and the image is indistinct. If, therefore, an object be so small, that, at the visual point, to be presently mentioned, the rays proceeding from it do not form an image of sufficient size on the retina, the object is not seen. To obviate this imperfection of the sense, minute bodies may be viewed through a small hole in a piece of paper or card, or with the instrument called a *microscope*. By looking through the small aperture in the paper or card, the object may be brought much nearer to the eye; the rays of greatest divergence are prevented by the smallness of the hole from impinging upon the retina; and the rest are converged to a focus upon that membrane, so that a sharp and distinct impression is received. The iris is, in this way, useful in effecting distinct vision,—the most divergent rays, being, by the contraction of the pupil, prevented from falling upon the crystalline.

Any object that does not subtend an angle of the sixtieth of a degree is invisible; but the visual power differs greatly in individuals. Some eyes are much more capable of minute inspection than others; and greater facility is acquired by practice. Professor Ehrenberg, however, found, that in regard to the extreme limits of vision, there is little difference among persons of ordinarily good sight, whatever may be the focal distance of their eyes. The smallest square magnitude usually visible to the naked eye, either of white particles on a black ground, or of black upon a white ground, is about the $\frac{1}{405}$th of an inch; but particles that reflect light powerfully, as gold dust, may be discovered with the naked eye in common daylight, when not exceeding the $\frac{1}{1125}$th of an inch; and, when the substance viewed is in lines instead of particles, it may be seen, if held towards the light, when only $\frac{1}{4900}$th of an inch in diameter.

[1] Op. citat., p. 249.

Again, there is a point of approximation to the eye beyond which objects cease to be distinctly seen, in consequence of the rays of light striking so divergently upon the eye, that the focus falls behind the retina. This point, too, varies according to the refractive power of the eye; and is, therefore, different in different individuals. In the myopic or short-sighted, it is much nearer the eye than common; in the presbyopic or long-sighted, more distant. The iris here, again, plays an important part, by its action in shutting off the most diverging rays.

There is also a limit beyond which objects are no longer visible. This is owing to the light from them becoming absorbed before it reaches the retina, or so feeble as not to make the necessary impression. The distance, consequently, at which an object may be seen, will depend upon the sensibility of the retina, and partly on the colour of the object; a light colour being visible to a greater distance than a darker. A distant object may also be imperceptible owing to the image, traced on the retina, being too minute to be appreciated; for the size of the image diminishes as the distance of the object increases. The range of distinct vision varies, likewise, with the individual,—and especially with the myopic and presbyopic; and in such case the pupil dilates to admit as much light as possible into the interior of the eye, and to compensate in some measure for the defect.

Between the ranges of distant and near vision, a thousand different examples occur. In all cases, however, the ocular cone must be brought to a focus on the retina, otherwise there cannot be perfect vision. It has been already observed, in the proem on light, that the distance, at which the ocular cone arrives at a focus behind the lens, is in proportion to the length of the objective cone; or, in other words, that the focus of a lens varies with the distance at which a radiant point is situate before it: where the point is near the lens the focus will be more remote behind it; and the contrary. If this occurs in the human eye it must necessarily follow;—either that it is not necessary for an object to be impressed upon the retina;—or that the eye is capable of accommodating itself to distances;—or if it does not occur, it must be admitted, that, owing to the particular constitution of the eye, the impressions are so made on the retina as not to need such adaptation. The whole bent of the foregoing observations on vision would preclude the admission of the *first* of these postulates. The *second* has been of almost universal reception, and given rise to many ingenious speculations; and the *third* has been seriously urged of late years only.

It would occupy too much space to dwell at length upon the various ingenious discussions, and the many interesting and curious experiments, that have resulted from a belief in the power possessed by the eye of accommodating itself to distances. It is a subject, however, which occupies so large a field in the history of physiological opinions, that it cannot be passed over. The chief views, that have been entertained, are:—*First.* The cornea or lens must recede from, or approach the retina, according to the focal distance, precisely as we adapt our telescopes by lengthening or shortening the tube. *Secondly.* If we suppose the retina to be stationary, the lens must experience a change in its

refractive powers, by an alteration of its shape or density; or, *Thirdly*. In viewing near objects, those rays only must be admitted, which are nearest the axis of the eye, and are consequently least diverging.

1. The hypothesis, that the adjustment of the eye is dependent upon an alteration of the antero-posterior diameter of the organ, or on the relative position of the humours and retina, has been strongly supported by many able physiologists. Blumenbach[1] was of opinion, and his views seem to have been embraced by Dr. Hosack,[2] that the four straight muscles of the eye, by compressing the eyeball, cause a protrusion of the cornea, and thus increase the length of the axis. Dr. Monro secundus[3] believed, that the iris, recti muscles, the two oblique, and the orbicularis palpebrarum participate in the accommodation; and Hamberger, Briggs,[4] and others, that the oblique muscles, being thrown in opposite directions around it, may have the effect of elongating the axis of the eye. Kepler[5] thought, that the ciliary processes draw the crystalline forward, and increase its distance from the retina. Des Cartes[6] imagined the same contraction and elongation to be effected by muscularity of the crystalline, of which he supposed the ciliary processes to be the tendons. Porterfield,[7] that the corpus ciliare is contractile, and capable of producing the same effect. Jacobson,[8] that the aqueous humour, by entering the canal of Petit through the apertures in it, distends the canal, and pushes the crystalline forward. Sir Everard Home,[9] that the muscular fibres, which he has described as existing between the ciliary processes, move the lens nearer to the retina, and that the lens is brought forward by other means, (which he leaves to conjecture,) when the distance of the object is such as to require it. Dr. Knox,[10] that the annulus albus, or the part which unites the choroid and sclerotic coats, is muscular, and the chief agent in this adjustment. Professor Mile,[11] of Warsaw, that the contraction of the iris changes the curvature of the cornea; whilst Sir David Brewster[12] thinks it "almost certain, that the lens is removed from the retina by the contraction of the pupil."

Without examining these and other views in detail, it may be remarked, that the nicest and most ingenious examination by the late Dr. Young[13] could not detect any change in the length of the axis of the eyeball. To determine this, he fixed his eye, and at the same time forced in upon the ball the ring of a key, so as to cause a very accurately defined phantom within the field of perfect vision; then looking

[1] Instit. Physiolog., § 276, or Elliotson's translation.
[2] Philosoph. Transact. for 1794, p. 146.
[3] Three Treatises on the Brain, the Eye, the Ear, p. 137, Edinb., 1797.
[4] Nova Visionis Theoria, Lond., 1685. [5] Haller, Element. Physiol., xvi. 4, 2.
[6] De Homine, p. 45, Lugd. Bat., 1664.
[7] A Treatise on the Eye, the Manner and Phenomena of Vision, Edinb., 1759.
[8] Magendie, Précis, &c., i. 78.
[9] Philosoph. Transact. for 1794, 1795, 1796, and 1797; and Lectures on Comparative Anatomy, iii. 213, Lond., 1823.
[10] Edinb. Philos. Transact., x. 56.
[11] Magendie, Journal de Physiologie, vi. 166; and Elliotson's Human Physiology, p. 571, Lond., 1840.
[12] Edinburgh Journal of Science, i. 77; and Treatise on Optics, op. citat., p. 253.
[13] Philos. Transact. for 1795.

to bodies at different distances, he expected, if the figure of the eye were modified, that the spot, caused by the pressure, would be altered in shape and dimensions; but no such effect occurred; the power of accommodation was as extensive as ever, and there was no perceptible change either in the size or figure of the oval spot. Again, Sir Everard Home asserts, that all the ingenuity of the distinguished mechanician, Ramsden, was unable to decide, whether, in the adjustment of the eye, there be any alteration produced in the curvature of the cornea. These facts would alone induce a doubt of the existence of this kind of adjustment, even if we had not the additional evidence, that many animals are incapable of altering the shape of the eyeball, by the muscles at least. The cetacea, the ray amongst fishes, and the lizard amongst reptiles, have the sclerotica so inflexible as to render any variation in it impossible.

With regard to many of the particular views that have been mentioned, they are mere "cobwebs of the brain," and unworthy of serious argument. In the action of the orbicularis palpebrarum, as suggested by Dr. Monro, there is, however, something so plausible, that many persons have been misled by it. He made a set of experiments to show, that this muscle, by compressing the eyeball, causes the cornea to protrude, and thus enables the eye to see near objects more distinctly. When he opened his eyelids wide, and endeavoured to read letters, which were so near the eye as to be indistinct, he failed; but when he kept the head in the same relation to the book, brought the edges of the eyelids within a quarter of an inch of each other, and made an exertion to read, he found he could see the letters distinctly. But Sir Charles Bell[1] properly remarks on this experiment, that if the eyelids have any effect upon the eyeball by their approximation, it must be to flatten the cornea; and that the improvement in near vision produced by such approximation, is owing to the most divergent rays being shut off,—as in the experiment of the pinhole through paper.

2. The second hypothesis, which attributes the adaptation to a change of figure in the crystalline itself, has been embraced by all who regard that body to be muscular, and therefore by Leeuwenhoek,[2] Des Cartes,[3] and Dr. Young.[4] These muscular fibres, however, could never be excited by Dr. Young to contraction so as to change the focal power; and their very existence is more than doubtful. The increasing density of the lens towards its centre indicates rather a cellular structure, the cells being filled with transparent matter of various degrees of concentration; and an examination into its intimate physical constitution affords no evidence of muscularity.

Professor Forbes,[5] of Edinburgh, embraced the view, that the adaptation is owing to a change of figure in the crystalline; but his explanation of its mode of production varies from that given by pre-

[1] Anat. and Physiology, Amer. edit. by Dr. Godman, ii. 227, New York, 1827.
[2] Boerhaav. Prælect., § 527, tom. iv. p. 92; and Haller, Element. Physiol., lib. xvi. sect. 2.
[3] Op. cit. [4] Op. citat.
[5] Proceedings of the Royal Society of Edinb., No. 25, cited in the Amer. Journ. of the Med. Sciences, Oct., 1845, p. 504.

ceding writers. The lens, he says, is composed of coats more firm and tenacious, as well as more refractive towards the centre, and less so at the sides. These coats are also nearly spherical in the centre, forming a nucleus of considerable resistance. Hence he supposes, that if the lens be compressed in any manner by a uniform hydrostatic pressure, it will yield more readily in a plane at right angles to the axis of vision; and the lens will become more spheroidal, and consequently more refractive,—that is, adapted for the vision of objects at small distances. This hydrostatic pressure is believed to be conveyed from the humours of the eye, between which the lens is delicately suspended, and to originate in the action of the muscles that move the eyeball compressing simultaneously the tough sclerotic coat.

It is somewhat singular, that on a subject where so many opportunities have occurred for establishing the fact definitively, such difference of opinion should exist regarding the question, whether an eye from which the crystalline has been removed, as in the operation for cataract, be capable of adjusting itself to near objects. Haller[1] and Knox, amongst others, decide the question affirmatively; Porterfield, Young, and Travers,[2] negatively. M. Magendie, as we have seen, considers the great use of the crystalline to be,—to increase the brightness and sharpness of the image by diminishing its size. Mr. Travers again, regards the adjustment as a change of figure in the lens; not, however, from a contractile power in the part itself, but in consequence of the lamellæ, of which it is composed, sliding over each other, when acted upon by external pressure; whilst upon the removal of this pressure, its elastic nature restores it to its former sphericity. The iris is conceived to be the agent in this process; the pupillary part of the organ being, in the opinion of Mr. Travers, a proper sphincter muscle, which, when it contracts and relaxes, tends, by the intervention of the ciliary processes, to effect a change in the figure of the lens, which produces a corresponding change in its refractive powers.

3. One of the causes to which the faculty of seeing at different distances has been ascribed is the contraction and dilatation of the pupil. It has been already observed, that when we look at near objects, the pupil contracts, so that the most divergent rays do not penetrate the pupil; and vision is distinct. Hence, it has been conceived probable, by De La Hire,[3] Haller,[4] and others, that the adjustment of the eye to various distances within the limits of distinct vision may be effected by this mechanism, in the same manner as it regulates the quantity of light admitted into the organ. Certain it is, that if we look at a row of minute objects, extending from the visual point outwards, the pupil is seen to dilate gradually as the axis of the eye recedes from the nearest object.

An experiment made by the author, on his own eye,[5] when a student of medicine, has been quoted by Dr. Fleming[6] as confirmatory of this

[1] Element. Physiol., lib. xvi. sect. 4.
[2] A Synopsis of the Diseases of the Eye, Lond., 1824.
[3] Mémoir. de l'Acad. des Sciences de Paris, tom. ix. p. 620.
[4] Element. Physiol., tom. v. lib. xvi., 4.
[5] Annals of Philosophy, x. 432.
[6] Philosophy of Zoology, i. 187, Edinb., 1822.

view. The extract of belladonna has the power, when applied to the eyelids, of dilating the pupil. A newly prepared article was thus applied, and in the space of about twenty minutes the pupil was so much dilated, that the iris was almost invisible. From the time that preternatural dilatation occurred, objects, presented to this eye with the other closed, were seen as through a cloud. The focus was found to be at twice the distance of that of the sound organ; but, in proportion as the effects of the belladonna passed off, and the pupil approached its natural size, vision became more and more distinct, and the focus nearer and nearer the natural. In the open air, all objects except those near were distinctly seen; but, on entering a room, all was enveloped in mist.

There is, indeed, more evidence in favour of the utility of contraction and dilatation of the pupil in distinct vision, within certain limits at least, than of any of the other supposed methods of adjustment; and, accordingly, the majority of opticians of the present day embrace this view of the subject; but without being able to explain satisfactorily the change in the interior of the eye effected by its movements. "It seems difficult," says Sir David Brewster[1]—one of the latest writers—"to avoid the conclusion, that the power of adjustment depends on the mechanism, which contracts and dilates the pupil; and as this adjustment is independent of the variation of its aperture, it must be effected by the parts in immediate contact with the base of the iris. By considering the various ways, in which the mechanism at the base of the iris may produce the adjustment, it appears to be almost certain, that the lens is removed from the retina by the contraction of the pupil." The conclusion, drawn by Sir David, does not, however, impress us with the same degree of certainty.

Müller[2] thinks it most probable, that the faculty of the eye, which enables it to adjust itself to different distances, depends on an organ, which has a tendency to act by consent with the iris, but yet is in a certain degree independent of it. Reasoning *per exclusionem*, he thinks it most probable, that the ciliary body has this motor power, and this influence on the position of the lens; but admits, that we have no positive proof of its possessing contractility. More recently, however, as has been shown,[3] the existence of a ciliary muscle has been demonstrated, which, by its contraction, may directly or indirectly advance the lens. M. Pouillet, in his lectures before the *Faculté des Sciences* of Paris,[4] explains the matter with no little confidence by the double effect of the crystalline being composed of different layers, and the mobility of the pupil;—a view, which had been previously maintained in its essential characters by Treviranus.[5] As these layers are thinner towards the axis of the crystalline than near its edges, by detaching them successively the curvature of the remainder becomes greater and greater, until the most central portion has the shape of a sphere. Hence, such an apparatus will not have one focus only, but several,—

[1] Op. citat., p. 252. [2] Elements of Physiology, by Baly, P. v. p. 1150. June, 1839.
[3] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, &c., p. 24, Lond., 1848.
[4] Elémens de Physique Expérimentale, t. iii. p. 331, Paris, 1832.
[5] Beiträge zur Anatom. und Physiol. der Sinnenwerkzeuge, u. s. w., 1828.

as many, in fact, as there are superposed layers;—the foci being nearer and nearer as we approach the central spherical portion. This arrangement, he says, enables us to see at all distances, inasmuch as, "having an infinite number of foci at our disposal, we can use the focus that suits the object we are desirous of viewing." If, for example, it be a near object, the pupil contracts, so as to allow the rays to fall only on the central parts; if more distant, the pupil is dilated to permit the rays to pass through a part that has a more distant focus.

It is obvious, however, that in such a case, the ordinary inconvenience of the aberration of sphericity must result; for when the pupil is dilated, the rays must pass through the more marginal, as well as the central part of the lens. M. Pouillet was aware of this difficulty, but he has not disposed of it philosophically. "It may be said that in opening the pupil widely, the light is not precluded from passing by the centre, and that a kind of curtain would be required to cover the part of the lens, which is unemployed. To this I reply, that there is no necessity to prevent the rays from passing by the axis of the crystalline; for what is the light, which passes through this small space, compared with that which passes through the great zone of the crystalline? It may be looked upon as null."

It must be admitted, with M. Longet,[1] that if the fact of the adaptation of the eye to vision at different distances be received as incontestable, the mechanism of the phenomenon must be regarded as entirely unknown; not one of the explanations offered being able to carry conviction. The whole affair is, indeed, enveloped in perplexity, and it is rendered not less so by the fact mentioned by M. Magendie, that if we take the eye of an albino animal, and direct it towards a luminous object, we find a perfect image depicted on the retina, whatever may be the distance of the object;—the image, of course, being smaller and less luminous when remote, but always distinct. Yet, in this experiment, the eye being dead, there can be neither contraction nor dilatation of the pupil. This result has induced Magendie[2]—and not too hastily, we think—to draw the conclusion, that although theory may suggest, that there ought to be such adaptation as has been presumed and attempted to be accounted for, observation proves, that such may not be the case; and, consequently, all the speculations on the subject, however ingenious they may be, must fall to the ground. Dr. Fletcher, too, after alluding to the various hypotheses on the subject, adds:—"It appears absurd to attempt to explain a fact which has no real existence, since it has never been proved that the eyeball has any capability of adapting itself to different distances, or that any such adaptation is required."[3] We are, indeed, not justified, perhaps, in admitting more than a slight accommodation from the contraction of the pupil in viewing near objects effected in the mode already explained. If the accommodation existed to any material extent, it is difficult to understand, why minor degrees of short or long-sightedness should not

[1] Traité de Physiologie, ii. 70, Paris, 1850.
[2] Précis Elémentaire, i. 72.
[3] Rudiments of Physiology, Part iii. p. 48, Edinburgh, 1837.

be rectified. Sir Charles Bell[1] conceives, "that the mechanism of the eye has not so great a power of adapting the eye to various distances as is generally imagined, and that much of the effect, attributed to mechanical powers, is the consequence of the motion of the pupil and the effect of light and of attention. An object looked upon, if not attended to, conveys no sensation to the mind. If one eye is weaker than the other, the object of the stronger eye alone is attended to, and the other is entirely neglected: if we look through a glass with one eye, the vision with the other is not attended to." "The mind," he adds, "not the eye, harmonizes with the state of sensation, brightening the objects to which we attend. In looking on a picture or panorama, we look to the figures, and neglect the background; or we look to the general landscape, and do not perceive the near objects. It cannot be an adaptation of the eye, but an accommodation, and association of the mind with the state of the impression."

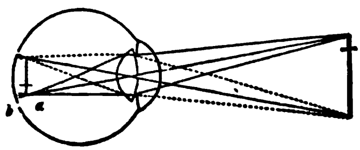
The view, which we have expressed upon the subject, is confirmed by the calculations of different investigators. From the refractive powers of the different media of the eye it was calculated by Olbers, that the difference between the focal distances of the images of an object at such distance that the rays are parallel, and of one at the distance of four inches, is only about 0.143 of an inch; so that the change in the distance of the retina from the lens required for vision at all distances, supposing the cornea and lens to maintain the same form, would not be more than about a line. Again:—M. de Simonoff,[2] a learned Russian astronomer, asserts, that from a distance of four inches to infinity the changes in the angle of refraction are so small that the apices of luminous cones, in a properly formed eye, must always fall within the substance of the retina; and hence no variation in the shape of the eye, according to the distance of the object, can be necessary. Such facts amply justify the interrogatory of M. Biot;[3]—whether the aberration of the focus for different distances may not be compensated in the eye by the intimate composition of the refractive bodies, as the aberration of sphericity probably is? Yet, if this be the case, how admirable must be the construction of such an instrument! how far surpassing any effort of human ingenuity! an instrument capable of not only correcting its own aberrations of sphericity, and refrangibility, but of seeing at all distances.[4]

It has been before observed, that the *visual point* varies in different individuals. As an average, it may be assumed at eight inches from the eye. There are many, however, who, either from original conformation of the organ, or from the progress of age, wander largely from this average; the two extremes constituting *myopy* or *short-sightedness*, and *presbyopy* or *long-sightedness*.

[1] Anat. and Physiology, edit. cit., ii. 230.
[2] Magendie's Journal de Physiologie, tom. iv. and Précis de Physiol., i. 73.
[3] Traité de Physiologie Expérimentale, Paris, 1816.
[4] Letters of Euler, by Sir D. Brewster, Amer. edit., i. 163, New York, 1833. See, on this subject, Volkmann, Art. Sehen, in Wagner's Handwörterbuch der Physiologie, 14te Lieferung, s. 295, Braunschweig, 1846; and Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation and Development, p. 20, Lond., 1848.

In the *myopic* or *short-sighted* the visual point is so close, that objects cannot be seen unless brought near the eye. This defect is owing to too great a refractive power in the transparent parts of the organ; or to too great a depth of the humours; or it may be caused by unusual convexity of the cornea or crystalline; or from the retina being too distant from the latter. From any one or more of these causes, the rays of light proceeding from distant objects, are brought to a focus before they reach the retina, and the objects consequently are not distinctly visible. (Fig. 119.) To see them distinctly, they must be placed close to the eye, in order that the rays may fall more divergently; and the focus be thrown farther back so as to impinge upon the retina. The defect may be palliated by the use of concave glasses, which render the rays, proceeding from the object, more divergent. It is by no means unfrequent in youth; and the myope has been consoled with the common belief, that, in the progress of life, and in the alterations which take place in the eye from age, he is likely to see well without spectacles, when others of the same age may find them essential. It is probable, however, that this is, in many cases at least, a vulgar error; as we have known different myopic sexagenarians, who have not experienced the slightest improvement.

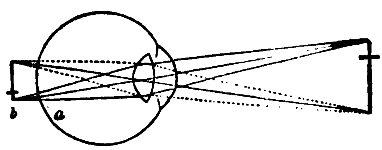
Fig. 119.



Myopic Vision.

The *presbyope*, *presbytic*, or *long-sighted* labours under an opposite defect. The visual point is much more distant than the average; and he is unable to see an object unless it is at some distance. This condition is owing to too feeble a refractive power in the transparent parts of the eye; to insufficient depth of the eyeball; to too close an approximation between the retina and crystalline; or to too little convexity of the cornea or crystalline; so that the rays of light proceeding from a near object are not rendered sufficiently convergent to impinge upon the retina; but fall behind it. This defect, which is experienced more or less by most people after middle age, is palliated by the use of convex glasses, which render the rays proceeding from an object more convergent, and enable the eye to refract them to a focus farther forward, or on the retina.

Fig. 120.



Presbyopic Vision.

Although the presbyopic eye is unusual in youth, it is sometimes met with. A young friend, at ten or twelve years of age, was compelled to employ spectacles adapted to advanced life; and this was the case with several of the members of a family, to whom the arts have been largely indebted in this country. One of them, at twenty, was compelled to wear spectacles which were almost microscopes.

Both the myopic and the presbyopic conditions exist in a thousand

degrees; and hence it is impossible to say, *à priori*, what is the precise lens, that will suit any particular individual. This must be decided by trial. The opticians have their spectacles arbitrarily numbered to suit different periods of life; but each person should select for himself such as will enable him to read without effort at the usual distance. A degree of myopy may be brought on by long-protracted attention to minute and near objects, as we observe occasionally in the watch-maker and engraver; and, again, a person who has been long in the habit of looking out for distant objects, as the sailor, or the watchman at signal stations, is rendered less fitted for minute and near inspection. During the domination of Napoleon, when the conscript laws were so oppressive, the young men frequently induced a myopic state, by the constant use of glasses of considerable concavity;—the defect being esteemed a sufficient ground of exemption from military service.

Another subject, which has given rise to much disputation and experiment, is, why, as we have two eyes, and the image of an object is impressed upon each of them, we do not see such object double? Smith[1] and Buffon[2] consider, that in infancy we do see it so; and that it is not until we have learned by experience,—by the sense of touch for example,—that one object only exists, that we acquire the power of single vision. After the mind has thus become instructed of its error, a habit of rectification is attained, until it is ultimately effected unconsciously. The objections to this hypothesis are many and cogent. We are not aware of any instance on record, in which double vision has been observed in those, who, having laboured under cataract from birth, have received their sight by an operation; and we are obviously precluded from knowing the state of vision in the infant, although the simultaneous and parallel motions of the eyes, which are manifestly instinctive, and not dependent upon habit, would induce us to presume, that the images of objects—as soon as the parts have attained the necessary degree of developement—are made to fall upon corresponding points of the retina. It may, also, be remarked, in favour of the instinctive nature of this parallel motion of the eyes, that in the blind,—although we may find much irregularity in the motions of the eyeball, owing to no necessity existing for the eyes being directed to any particular point,—the eyeballs move together, unless some deranging influence is exerted. The truth is, as we have already observed, the encephalon is compelled to receive the impression as it is conveyed to it; and even in cases, in which we are aware of an illusion, the perception of the illusion still exists in spite of all experience. If the finger be pressed on one side of the eyeball, an object, seen in front, will appear double, and the perception of two objects will be made by the brain, although we know from experience that one only exists. This occurs in all the various optical illusions to be presently mentioned.

The effect of intoxication has been adduced in favour of this hypothesis. It is said that in these cases the usual train of mental association is broken in upon, and hence double vision results. The proper

[1] Optics, Cambridge, 1738.
[2] Mémoir. de l'Académ. des Sciences, 1743.

explanation, however, of this diplopia of the drunkard rests upon other grounds. The effects of inebriating substances on the brain are to interfere with all its functions; and most sensibly, with the voluntary motions, which become irregularly executed. The voluntary muscles of the eye partake of this vacillation, and do not move in harmony, so that the impressions are not made on corresponding points of the retina, and double vision necessarily results.

Another hypothesis has been, that although a separate impression is made upon each retina,—in consequence of the union of the optic nerves, the impressions are amalgamated, and arrive at the encephalon, so as to cause but one perception. This was the opinion of Briggs,[1] and Ackermann; and at one time it was generally received. Dr. Wollaston[2] supposed the consentaneous motion of the eyes to be connected with the partial union of the optic nerves. The anatomical and physiological facts relating to the union and decussation of these nerves have already engaged us. By a reference to that subject it will be found, that a true decussation takes place between them, yet that each eye probably has its distinct nerve from origin to termination; and that no such semi-decussation, as that contended for by Dr. Wollaston, exists. These facts are unfavourable to the hypothesis of amalgamation of impressions: besides, if we press slightly on the eye, we have a double impression, although the relation of the optic nerves to each other is the same; and, moreover, the same explanation ought to apply to audition, in which we have two distinct impressions, but only a single perception:—yet no one conceives that the auditory nerves decussate. The fusion of the two images into one seems to be a mental operation.

Another opinion has been maintained;—that we do not actually receive the perception of two impressions at the same time; and that vision consists in a rapid alternation in the use of the eyes, according as the attention is directed to one or other of them by accidental circumstances. Such was the opinion of M. Dutours.[3] A modification of this view was entertained by M. Le Cat,[4] who asserts, that, although the right eye is not always the most powerful, it is most frequently employed; and Gall denies, that we use both eyes at the same time, except in the passive exercise of the function. In active vision, he asserts, we always employ one eye only,—sometimes one and sometimes the other; and thus, as we receive but one impression, we necessarily see but one object. In support of this view, he remarks that in many animals the eyes are situate at the sides of the head, so as not to be capable of being directed together to the same object. In them, consequently, one eye alone can be used; and he considers this a presumption, that such is the case in man. He remarks farther, that in many cases we use one eye by preference, in order that we may see better—as in shooting or in taking the direction of objects in a straight line; and that although, in other cases, both eyes may be open, we still use but one. In proof of this, he says, if we place a small object between the eyes and a lighted body, and look at the latter, the shade

[1] Nova Visionis Theoria, Lond., 1685. [2] Philos. Transact. for 1824, p. 222.
[3] Mémoir. présentées à l'Académie des Sciences, &c., t. iii. & iv. [4] Op. citat.

does not fall between the eyes, on the root of the nose, as it ought to do if the body were looked at with both eyes; but on each eye alternately, according as the one or the other is directed to it; and, he adds, if, when we squint voluntarily, we see two objects, it is because one eye sees passively, whilst the other is in activity.[1]

Amongst numerous objections to this view of the subject, a few may be sufficient. Every one must have observed how much more vividly an object is seen with both eyes than with one only. The difference according to Jurin[2] is a constant quantity; and, in sound eyes of the ordinary degree of power, amounts to one-thirteenth of the whole effect. But we have experiment to show, that a distinct impression is made upon each eye. If a solar beam be admitted into a dark chamber, and be made to pass through two glasses of tolerable thickness, but of different colours, placed close alongside each other, provided the sight be good and the eyes of equal power the light perceived will not be of the colour of either of the glasses, but of an intermediate shade; and if this should not happen, it will be found, that the eyes are of unequal power. When such is the case, the light will be of the colour of the glass placed before the stronger eye. These results were obtained in the *Cabinet de Physique* of the *Faculté de Médecine* of Paris, by M. Magendie,[3] in the presence of M. Tillaye the younger.

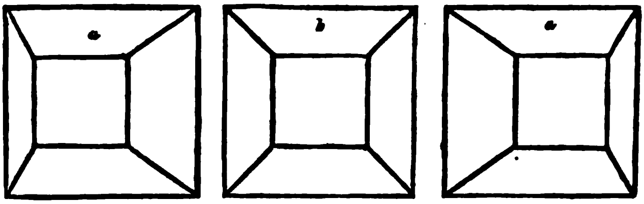
The existence of this double impression is proved in another way. If we place any tall, slender object a few feet before us, and examine its relative situation compared with a spot on a wall in the distance, we find, that if the spot be hidden by the stick, when both eyes are open, it will become visible to each eye, when used singly; and be seen on the side of the stick corresponding to the eye employed. But Professor Wheatstone[4] has instituted experiments, which place this matter entirely at rest. He has shown, that in viewing an object having length, breadth, and thickness, the perspective projections upon the two retinæ differ according to the distance at which the object is placed before the eyes. If so distant, that to view it the optic axes must be parallel, the two projections are precisely similar; but if so near, that to view it the optic axes must converge, a different perspective projection is presented to each eye, and these perspectives become more dissimilar as the convergence of the optic axes becomes greater. Notwithstanding this dissimilarity between the two pictures, which is in some cases very great, the object is still seen single, although not exactly resembling either of the two pictures on the retinæ.

Having thus established, that the mind perceives an object of three dimensions by means of the two dissimilar pictures projected by it on the two retinæ, Mr. Wheatstone inquired what would be the visual effect of presenting simultaneously to each eye instead of the object itself its projection on a plane surface as it appears to that eye? For this purpose he imagined an instrument which he calls *stereoscope*. It

[1] Adelon, Physiologie, 2de édit., i. 457, Paris, 1829.
[2] Essay appended to Smith's Optics, Cambridge, 1738; and Haller, Element. Physiol., lib. xvi. 4.
[3] Précis, &c., i. 86. Dutours, in Mém. présentées à l'Académ., iii. 514, & iv. 499.
[4] Philosophical Transactions, P. ii., Lond., 1838.

consists of two plane mirrors, with their backs inclined to each other at an angle of 90°, near the faces of which two monocular pictures are so disposed, that their reflected images are seen by the two eyes, each looking into one of the mirrors on the same plane. The experiment may, however, be made sufficiently well by the subjoined figures.

Fig. 121.



Binocular Vision.—Professor Wheatstone's Experiment.

Fix the right eye on the right-hand figure, and the left eye on the left-hand figure; hold between the eyes, in front of the nose, the board of an octavo book. The two figures *a a* will be seen to approximate, and to run into one, representing the skeleton of a truncated four-sided figure in bold relief, *b*;—a fact, which shows, that the visual appreciation of solidity or projection arises from the combination in the mind of two different images. These could not exist in a person who has never had more than one eye; and therefore from sight alone he could form no notion of solidity. He would have to combine with sight the evidence afforded by touch.

All these facts demonstrate, that two impressions are really made in all cases,—one on each eye;—and yet the brain has perception of but

Fig. 122.

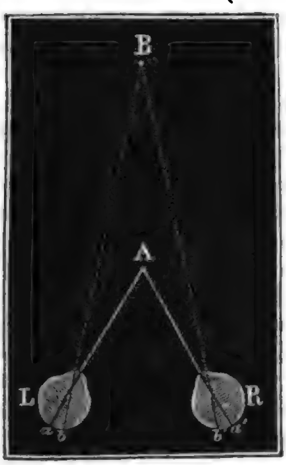
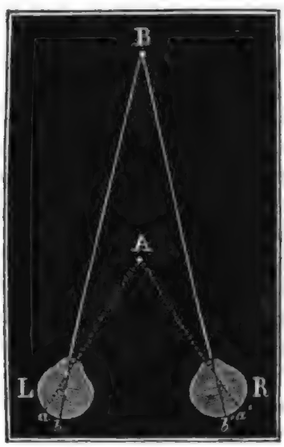


Fig. 123.

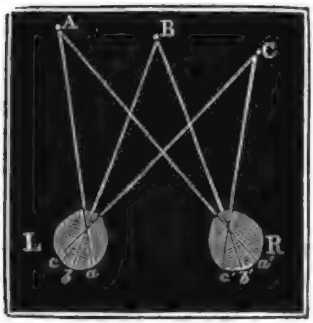


Binocular Vision.

one. If the law of visible direction, which Sir David Brewster has pointed out (see page 258), be adopted, the cause of single vision with two eyes must be admitted as a necessary consequence. If we are

placed at one end of a room, and direct the axes of both eyes to a circular aperture in a window-shutter at the other end, although an image of this aperture may be formed in each eye, yet because the lines of visible direction from similar points of the one image meet the lines of visible direction from similar points of the other, each pair of similar points will appear as one point, and the aperture seen by one eye will exactly coincide with the aperture seen by the other. But if, when an object is seen single with both eyes, we press one eye aside, the image formed by that eye will separate from the other image, and the object will appear double; or, if the axes of both eyes be directed to a point either nearer or more remote than the aperture in the window-shutter, then, in both these cases, the aperture will appear double, because the similar lines of visible direction no longer meet at the aperture.[1] In Fig. 122, if we look at the object A, the more distant object, B, will be seen double; and in Fig. 123, if we look at the object B, the nearer object A will be seen double. It is not necessary, however, that the axes of the eyes should be directed accurately on an object, in order that it shall be seen single with both eyes. A whole range of objects may be seen single if their images are thrown on corresponding parts of the retina in both eyes, as in Fig. 124.

Fig. 124.



Binocular Vision.

After all, perhaps the true condition of single vision is, that the two images of an object should be formed on portions of the two retinæ that are accustomed to act in concert. In cases of convergent strabismus, the patient does not see double; but immediately after a successful operation, if the vision of the two eyes be good, he does so; and this continues until the parts of the two retinæ have become habituated to act in concert.

In the course of the preceding remarks, it was stated, that the eyes are not always of the same power. The difference is sometimes surprising. M. Adelon[2] mentions the case of a person, one of whose eyes required a *convex* glass, with a focus of five inches; the other a *concave* glass, with a focus of four inches. In these cases, it is important to use one unassisted eye only; as confusion must necessarily arise from directing both to an object. This is the cause why we close one eye in looking through a telescope. The instrument has the effect of rendering the focal distance of the two eyes unequal, and of placing them in the same situation as if they were, originally, of different powers.

From what has been said it will be understood, that if from any cause, as from a tumour pressing upon one eyeball, from morbid debility of the muscles, or from want of correspondence in the sensibility of the two retinæ, the eyes be not properly directed to an object,

[1] Optics, p. 44, in Library of Useful Knowledge, Natural Philosophy, vol. i., Lond., 1829, and Treatise on Optics, edit. cit.

[2] Physiologie, edit. cit., i. 459.

double vision will be the consequence. In almost all cases, however, of distortion of the eyeballs, the image falls upon a part of one retina, which is more sensible than the portion of the other on which it falls; the consequence will be, that the mind will acquire the habit of attending to the impression on one eye only; and the other may be so neglected, that it will assume a position to interfere as little as possible with the vision of its fellow:—so that, although at first, in *squinting*, there may be a double impression, vision is ultimately single. Buffon,[1] who was of this opinion, affirms, that he examined the eyes of many squinters, and found that they were of unequal power; the weaker, in all cases, having turned away from its direction, and generally towards the nose, in order that fewer rays might reach it, and consequently vision be less interfered with. Yet it is always found, if the sound eye be closed, that the other resumes its proper direction; a fact which disproves the idea of De La Hire[2] and others that the cause of *strabismus* or *squinting* is a difference of sensibility in the corresponding points of the retinæ, and that the discordance in the movements of the organs occurs in order that the images may still fall upon points of the retinæ that are equally sensible. According to this view, both eyes must of course act.

The fact of the diverted eye resuming its proper direction when the sound one is closed is of practical application. Many of the cases of squinting that occur in infancy have been caused by irregular action in the muscles of the eyeball; so that certain of them, from accident or imitation, having been used more frequently than others, the due equilibrium has not been maintained; double vision has resulted; and the affected eye has gradually attained its full obliquity. In these cases, we can, at times, remedy the defect, by placing a bright or conspicuous object in such a position as to exercise the enfeebled muscles; or, we can compel the whole labour of vision to be effected by one eye, and *that* the affected one, which, under the stimulus, will be correctly executed, and, by perseverance, the inequality may be obviated. These, indeed, are the only cases in which we can expect to afford relief; for if the defect be in the interior of the eye, in a radical want of correspondence between the retinæ, or in inequality of the foci, it is irremediable.

It would appear, then, that in confirmed squinting, one eye is mainly, if not solely used, and vision is single,—and that the inclination of one eye inwards may be so great as to deprive it of function, or so slight as to allow the organ to receive rays from the same object as its fellow, and although on different parts of the retina, yet they may become associated; but, in either case, it would seem, that they, who squint habitually, neglect the impressions on the distorted eye, and see with but one.

It has been remarked, that the eyeball of the imperfect eye is drawn towards the nose, in order that as few rays as possible may penetrate the organ, and the vision of the sound eye be less liable to confusion. Sir Everard Home[3] conceives, that it takes this direction in consequence

[1] Mém. de l'Académie, 1743, p. 231.
[2] Ibid., tom. ix. 530; Jurin, in Essay appended to Smith's Optics, §§ 178–194.
[3] Philos. Transact., 1797, and Lectures on Comparative Anatomy, iii. 238, Lond., 1823.

of the adductor muscle being stronger, shorter, and its course more in a straight line than that of any of the other muscles; and Sir Charles Bell[1] ingeniously applies his classification of the muscles of the eye to an explanation of the fact. He asserts, that the recti muscles are in activity whilst attention is paid to the impression on the retina,—but that, when the attention is withdrawn, the recti are relieved, and the eyeball is given up to the influence of the oblique muscles, whose state of equilibrium exists when the eyeball is turned, and the pupil presented, upwards and inwards.

Lastly, in persons who are in the habit of making repeated celestial observations, or in those who make much use of the microscope, the attention is so entirely directed to one eye, that the other is neglected, and, in time, wanders about, so as to produce squinting at the pleasure of the individual. In these cases, the eyes become of unequal power; so that one only can be employed where distinct vision is required.

Thus far our remarks have been directed to double vision, where both eyes are employed. We have now to mention a singular fact connected with double and multiple vision with one eye only. The author has distinct double vision with each eye; a lighted lamp, for example, presenting to one, with the other closed, two defined images, the one in advance of the other. If a hair, a needle, or any small object be held before one eye—the other being closed—and within the point of distinct vision, so that the bright light of a lamp or from a window shall fall upon the object in its passage to the eye, or be reflected from it—we appear to see not one object but many. This fact, when it was first observed by the author, appeared to him to have escaped the observation of opticians and physiologists, inasmuch as it had not been noticed in any of the works recently published on optics or physiology. On reference, however, to the excellent "system," of Smith,[2] on the former subject, he found in the "Essay upon Distinct and Indistinct Vision" by Dr. Jurin, appended to it, the whole phenomenon explained, and elucidated at considerable length. The elaborate character of the explanation is probably the cause, why the fact has not been noticed by subsequent writers. The best way of trying the experiment is that suggested by Dr. Jurin. Take a parallel ruler, and opening it slightly, hold it directly before the eye, so as to look at a window or lamp through the aperture. If the ruler be held at the visual point, the aperture will appear to form one luminous line; but if it be brought nearer to the eye, it will appear double; or as two luminous lines, with a dark line between them; and according as the aperture is varied—or the distance from the eye—two, three, four, five or more luminous and dark parallel lines will be perceptible.

At first sight, it might seem, that this phenomenon should be referred to the diffraction or inflection, which light experiences in passing by the edges of a small body,—as the hair or needle. Newton had long ago shown, that, when a beam of light shines upon a hair, the hair will cast several distinct shadows upon a screen, and, of course, present several images to the eye. Dr. Rittenhouse[3] explains, on the same principle, a

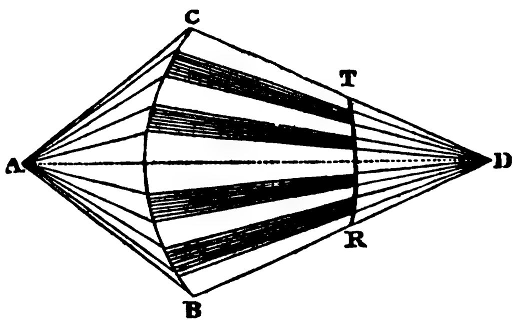
[1] Anat. and Physiol., edit. cit., ii. 235.
[2] Optics, edit. cit.
[3] Amer. Philos. Transact., vol. ii.

curious optical appearance, noticed by Mr. Hopkinson, in which, by the inflection of light, caused by the threads of a silk handkerchief, a multiple image of a distant lamp was presented. The objections, however, to the explanation by inflection are,—that the image always appears single, if the object be not *within* the distance of distinct vision;—and that the same multiple image is presented, when the object is seen by reflection, as when we look at a fine line drawn upon paper; or at a fine needle held in a bright light. In this case, a considerable number of parallel images of the needle may be seen, all equally or nearly equally distinct; and not coloured.

Dr. Jurin considers the phenomena to be caused by fits of easy refraction and reflection of light. Newton demonstrated, that the rays of light are not, in all parts of their progress, in the same disposition to be transmitted from one transparent medium into another; and that sometimes a ray, which is transmitted through the surface of the second medium, would be reflected back from that surface, if the ray had a little farther to go before it impinged upon it. This change of disposition in the rays,—to be either transmitted by refraction, or to be reflected by the surface of a transparent medium,—he called their *fits of easy refraction*, and *fits of easy reflection;* and he showed, that these fits succeed each other alternately at very small intervals in the progress of the rays. Newton does not attempt to explain the origin of these fits, or the cause that produces them; but it has been suggested, that a tolerable idea of them may be formed by supposing, that each particle of light, after its emanation from a body, revolves round an axis perpendicular to the direction of its motion, and presents alternately to the line of its motion an attractive and a repulsive pole, in virtue of which it will be refracted, if the attractive pole be nearest any refracting surface on which it falls; and reflected, if the repulsive pole be nearest the surface.

A less scientific notion of the hypothesis has been suggested; by supposing a body with a sharp and a blunt end passing through space, and successively presenting its sharp and blunt ends to the line of its motion. When the sharp end encounters any soft body it penetrates it; but when the blunt end encounters the same body, it is reflected or driven back. In applying this explanation to the phenomenon in question, Dr. Jurin presumes, that the light, in passing through the humours of the eye, experiences these fits of easy refraction and easy reflection. This will be elucidated by the marginal figure, Fig. 125. Suppose a number of rays of light to proceed from the point A, and to impinge, with dif-

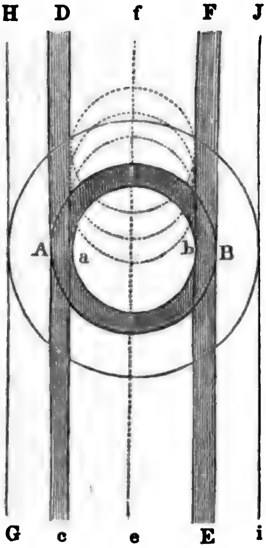
Fig. 125.



Multiple Vision with One Eye.

ferent degrees of obliquity, on the denser medium, B C; all the rays that are in fits of easy refraction will pass through the medium to the point D; whilst those that are in fits of easy reflection, will be thrown back into the medium A B C; so that we may presume, that all the rays, which fall upon the parts of the medium B C, corresponding to the bases of the dark cones, will be reflected back, whilst those that correspond to the bases of the light cones, will pass to a focus at D. Now, if all the bundles of rays, transmitted through the surface B C, be accurately collected into a focus, no other consequence will arise from the other bundles of rays having been reflected back, than that the focus will be less luminous than it would have been had all the rays been transmitted through it. This explains why, at the distance of distinct vision, we have only a single impression made on the eye. But if we approach the object A, so that the focus is not thrown,—say upon the screen R T, which may be presumed to represent the retina — but behind it; the dark and light spaces will be represented upon the screen, and, of course, in concentric circles. This happens to the eye, when the hair or needle or other object is brought nearer to it than the visual point. We can thus understand, why concentric circles, of the nature mentioned, should be formed upon the retina; but how is it, that the objects seen preserve their linear form? Suppose a b, Fig. 126, to be a luminous cone, which in a fit of easy refraction has impinged upon the retina; and A B, b a, the concentric circles, corresponding to the rays that have been reflected. It is obvious, that every point of the object will be the centre of so many concentric circles on the retina; and if we imagine the fits of easy reflection and refraction to be the same around those points, we shall have the dark and lucid lines represented by the tangents to these circles; and hence we can comprehend why, instead of having one lucid line e f, we have three, separated by dark lines parallel to them; and if the light from the luminous point be strong enough to form more lucid rings than are represented in Fig. 126, and the breadth of those rings be not too minute to be perceived, we may have the appearance of five, seven, or more lucid lines, separated by parallel dark lines.

Fig. 126.



Multiple Vision with One Eye.

The undulatory theory of light offers another explanation of the phenomenon of fits. The waves in the luminous ether along a ray of light, may meet the surface of a transparent body in different conditions of condensation or rarefaction, and their transmission or reflection may be determined by these conditions.

We proceed now to consider the advantages, which the mind derives from the possession of this sense, so pre-eminently entitled to the epithet

intellectual. Its immediate function is to give us the sensation of light and colour. In this it cannot be supplied by any of the other senses. The action is, therefore, the result of organization; or is a "law of the constitution;" requires no education; but is exercised as soon as the organ has acquired the proper developement. Yet, occasionally, we meet with cases, in which the eye appears to be totally insensible to certain colours, although capable of performing the most delicate functions of vision. Sir David Brewster[1] has collected several of these cases from various sources. A shoemaker of the name of Harris, at Allonby, in Cumberland, could only distinguish *black* and *white;* and whilst a child, could not discriminate the cherries on a tree from the leaves, except by their shape and size. Two of his brothers were almost equally defective. One of them constantly mistook *orange* for *grass green*, and *light green* for *yellow*. A Mr. Scott, who describes his own case,[2] mistook *pink* for *pale blue*, and full *red* for full *green*. His father, his maternal uncle, one of his sisters, and her two sons, had the same defect. A Mr. R. Tucker, son of Dr. Tucker, of Ashburton, mistakes *orange* for *green*, like one of the Harrises; and cannot distinguish *blue* from *pink*, but almost always knows *yellow*. He mistakes *red* for *brown*, *orange* for *green*, and *indigo* and *violet* for *purple*. A tailor at Plymouth, whose case is described by Mr. Harvey,[3] of Plymouth, regarded the solar spectrum as consisting only of *yellow* and *light blue;* and he could distinguish, with certainty, only *yellow*, *white* and *gray*. He regarded *indigo* and *Prussian blue* as *black;* and *purple* as a modification of *blue*. *Green* puzzled him exceedingly; the darker kinds appearing to him *brown*, and the lighter kinds a pale *orange*. On one occasion, he repaired an article of dress with *crimson* instead of *black* silk; and on another occasion patched the elbow of a *blue* coat with a piece of *crimson* cloth. A still more striking case is given by Dr. Nicholls[4] of a person in the British navy, who purchased a blue uniform coat and waistcoat, with red breeches to match. Sir David Brewster refers to a case that fell under his own observation, where the gentleman saw only the *yellow* and *blue* colours of the spectrum. This defect was experienced by Mr. Dugald Stewart,[5] who was unable to perceive any difference between the colour of the scarlet fruit of the Siberian crab and that of its leaves. Dr. Dalton,[6] the chemist and philosopher,—after whom the defect has been most unjustifiably termed *daltonism*,—could not distinguish *blue* from *pink* by daylight; and in the solar spectrum, the *red* was scarcely visible; the rest of it appearing to consist of two colours, *yellow* and *blue*. Mr. Troughton, the optician, was fully capable of appreciating only *blue* and *yellow;* and when he named colours, the terms *blue* and *yellow* corresponded to the more or less refrangible rays:—all those that belong to the former, exciting the sensation of blueness; and those that belong to the latter that of yellowness. Dr. Hays,[7] who has collected the history of nume-

[1] Optics, edit. cit.; Letters on Natural Magic; and art. Optics, in Library of Useful Knowledge.

[2] Philos. Trans. for 1778.

[3] Edinb. Phil. Transact., x. 253.

[4] Medico-Chirurgical Trans., vii. 477, ix. 359.

[5] Elements of the Philosophy of the Human Mind, ch. iii.

[6] Manchester Memoirs, v. 28.

[7] Proceedings of the American Philosophical Society for August 21, 1840.

rous cases of achromatopsia,—as this defect has been termed,—and has added the history of one which fell under his own care, was led to infer, from all his researches: 1, that entire inability of distinguishing colours may co-exist with perfect ability to perceive the forms of objects; 2, that the defect may extend to all but one colour, and in such case the colour recognised is always yellow; and, 3, that the defect may extend to all but two colours, and in such case the colours recognised are always yellow and blue;—yet that this is not the fact is sufficiently shown by the examples already given. Dr. Pliny Earle[1] has referred to a number of cases, which came within his knowledge, and most of them under his own observation, in which the inability would seem to have been hereditary. Dr. Earle's maternal grandfather and two of his brothers were characterized by it; and among the descendants of the first mentioned, it is met with in *seventeen*. When thus entailed, it would appear to overleap, at times, one generation or more. It would appear, too, that males are more frequently affected than females. Dr. Earle observed, that the power of accurately distinguishing colours varies at different times in the same person; and that it is not unfrequently connected with, or accompanied by, a defect in the power of discriminating musical tones.

The opinions of philosophers have varied regarding the cause of this singular defect in eyes otherwise sound, and capable of performing every other function of vision in the most delicate and accurate manner. By some, it has been presumed to arise from a deficiency in the visual organ; and by such as consider the ear to be defective in function in those that are incapable of appreciating musical tones, this deficiency in the eye is conceived to be of an analogous nature; and the analogy is farther exhibited by the facts, just mentioned, observed by Dr. Earle. "In the sense of vision," says Dr. Brown,[2] "there is a species of defect very analogous to the want of musical ear,—a defect which consists in the difficulty, or rather the incapacity, of distinguishing some colours from each other—and colours which, to general observers, seem of a very opposite kind. As the want of musical ear implies no general defect of mere quickness of hearing, this visual defect, in like manner, is to be found in persons who are yet capable of distinguishing, with perfect accuracy, the form, and the greater or less brilliancy of the coloured object; and I may remark, too, in confirmation of the opinion, that the want of musical tone depends on causes not mental but organic, that in this analogous case some attempts, not absolutely unsuccessful, have been made to explain the apparent confusion of colours by certain peculiarities of the external organ of sight."

Dr. Dalton, who believed the affection to be seated in the physical part of the organ, has endeavoured to explain his own case, by supposing, that the vitreous humour is *blue*, and therefore absorbs a great portion of the red and other least refrangible rays; and Sir David Brewster, in the "Library of Useful Knowledge,"[3] appears to think

[1] American Journal of the Medical Sciences, April, 1845, p. 346.
[2] Lectures on the Philosophy of the Human Mind, vol. i., Boston, 1826.
[3] Natural Philosophy, vol. i., Optics, p. 50, Lond., 1829.

that it may depend upon a want of sensibility in the retinæ, similar to that observed in the ears of those who are incapable of hearing notes above a certain pitch; but as this view is not contained in his more recent "Treatise on Optics," it is probably no longer considered by him to be satisfactory.

The defect in question—difficult as it is to comprehend—has always appeared to the author to be entirely cerebral, and to strikingly resemble, as Dr. Brown has suggested, the "want of musical ear." As we have already endeavoured to establish, that the latter is dependent upon a defective mental appreciation, the parity of the two cases will, of course, compel us to refer the visual defect, or the want of the "faculty of colouring," to the same cause. It has been remarked, that the eye in these cases exercises its function perfectly as regards the form and position of objects, and the degree of illumination of their different portions. The only defect is in the conception of colour. The nerve of sight is probably accurately impressed, and the deficiency is in the part of the brain whither the impression is conveyed, and where perception is effected, which is incapable of accurately appreciating those differences between rays, on which their colour rests; and this is the view taken of it by one of the most eminent philosophers of the present day, Sir J. F. W. Herschel.[1]

The *mediate* or *auxiliary* functions of vision are numerous; hence, the elevated rank that has been assigned to it. By it, we are capable of judging, to a certain extent, of the direction, position, magnitude, distance, surface, and motion of bodies. Metaphysicians have differed greatly in their views on this subject; the majority believing, that, without the sense of touch, the eye is incapable of forming any accurate judgment on these points; others, that the sense of touch is no farther necessary than as an auxiliary; and that a correct appreciation could be formed by sight alone. The few remarks that may be necessary on this subject will be deferred until the physical and other circumstances which enable us to judge of distance, &c., have been canvassed.

The *direction* or *position* of objects has already been considered, so far as regards the inverted image formed by them on the retina. The errors that arise on this point are by no means numerous, and seldom give rise to much inconvenience; yet, whenever the luminous cone meets with reflection or refraction before reaching the eye, the retina conveys erroneous information to the sensorium, and we experience an *optical illusion*.

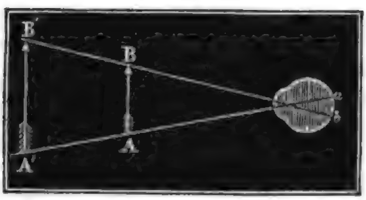
To ascertain the *magnitude*, *distance*, and *surface* of bodies, we are obliged to take into consideration several circumstances connected with the appearance of the object,—such as its apparent size; the intensity of light, shade, and colour; the convergence of the axes of the eyes; the size or position of intervening objects, &c. Porterfield[2] enumerates six methods, which are employed in appreciating distance—1. The

[1] Encyclopædia Metropolitana, art. Light.
[2] A Treatise on the Eye, ii. 409, London, 1759.

apparent magnitude of objects; 2. The vivacity of their colours; 3. The distinction of their smaller parts; 4. The necessary conformation of the eyes for seeing distinctly at different distances; 5. The direction of their axes; and 6. The interposition of objects. Dr. Brown[1] reduces them to three—1. The difference of the affections of the optic nerve; 2. The different affections of the muscles, employed in varying the refracting power of each eye, according to the distance of objects, and in producing that particular inclination of the axes of the two eyes which directs them both equally on a particular object; and 3. The previous knowledge of the distance of other objects, "which form, with that we are considering, a part of one compound perception." Lastly, Dr. Arnott[2] enumerates four modes by which this is effected—1. The space and place, occupied by objects in the field of view, measured by what is termed the *visual angle*. 2. The intensity of light, shade, and colour. 3. The divergence of the rays of light—and 4. The convergence of the axes of the eyes. This enumeration may be adopted with some slight modifications. The circumstances, in our opinion, to be considered, are:—

1. The *visual angle*, or that formed by two lines, which shave the extremities of an object and cross at the centre of the crystalline; so that the *visual angle*, subtended by the object, as A B, Fig. 127, is exactly equal to that subtended by its image *a b* on the retina. It is obvious, from this figure, that if all objects were equidistant from the eye, and of the same magnitude, they would subtend the same angle; and if not of the same magnitude, the difference would be accurately indicated by the difference of the visual angles subtended by them. The two arrows, however, which are of different sizes, subtend the same visual angle, and are alike represented on the retina by the image *a b*. It is clear, then, that the visual angle does not give us a correct idea of the relative magnitudes of bodies, unless we are acquainted with their respective distances from the eye; and, conversely, we cannot judge accurately of their distances, without being aware of their magnitudes. A man on horseback, when near us, subtends a certain visual angle; but, as he recedes from us, the angle becomes less and less; yet we always judge accurately of his size, because aware of it by experience; but if objects are at a great distance, so as not to admit of their being compared with nearer, by simple vision, we are in a constant state of illusion,—irresistibly believing, that they are much smaller than they really are. This is the case with the heavenly bodies. The head of a pin held close to the eye subtends as large a visual angle as the planet Jupiter, which is one thousand two hundred and eighty-one times bigger than this earth, and is eighty-six thousand miles in diameter. In like manner, a five-cent piece, held at some

Fig. 127.

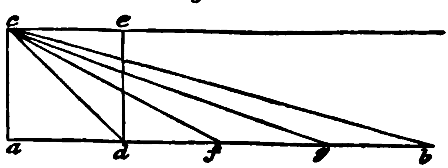


Visual Angle.

[1] Lectures on the Philosophy of the Human Mind, vol. i., Boston, 1826.
[2] Elements of Physics, new Amer. edit., p. 383, Philad., 1841.

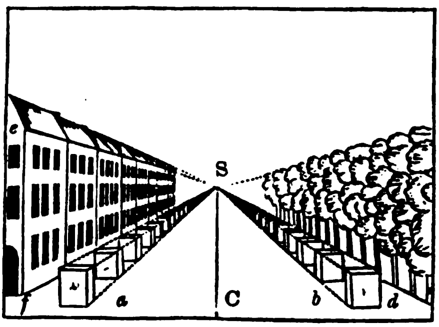
distance from the eye, shuts off the sun, although its diameter is eight hundred and eighty-eight thousand miles. The sun and moon, again, by subtending nearly the same visual angle, appear to us of nearly the same size; and the illusion persists in spite of our being aware of the mathematical accuracy with which it has been determined, that the former is ninety-six millions of miles from us, and the latter only two hundred and forty thousand. The visual angle, again, subtended by an object, differs greatly according to the position of the object. A sphere has the same appearance or bulk, when held at a certain distance from the eye, whatever may be the position in which it is viewed; and, accordingly, the visual angle, subtended by it, is always identical. Not so, however, with an oval. If held, so that the rays from one of its ends shall impress the eye, it will occasion a circular image, and subtend a much smaller angle than if viewed sideways, when the image will be elliptical, or oval. The same thing must occur with every object, whose longitudinal and transverse diameters differ. It is obvious, that if any such object be held in a sloping position towards the eye, it will appear more or less shortened; in the same manner as the slope of a mountain or inclined plane would appear much greater, if placed perpendicularly before the eye. This appearance is what is called *foreshortening;* and it may be elucidated by the following figure. Suppose a man to be standing on a level plain, with his eye at *c* (Fig. 128), looking down on the plain. The portion of the surface *a d*, which is next to him, will be seen without any foreshortening; but if we suppose him to regard successively the portions *d f*, *f g*, and *g b* of the plain, the angle, subtended by each portion, will diminish; so that if the angle *a c d* be 45°, *d c f* will be 18°, *f c g* 8°, and so on; until, at length, the obliquity will be so great, that the angle becomes inappreciable. This is the cause why, if we look obliquely upon a long avenue of trees, we are unable to see the intervals between the farthest in the series; although that between the nearest to us may be readily distinguished. In all paintings, of animals especially, the principle of foreshortening has to be rigidly attended to; and it is owing to a neglect of this that we see such numerous distorted representations—of the human figure especially. It has been already stated, that objects appear smaller according to their distance; hence, the houses of a

Fig. 128.



Foreshortening.

Fig. 129.



Perspective.

street, or the trees of an avenue, that are nearest to us, or in the foreground, form the largest images on the retina, and there is a gradual diminution, so that, if we could imagine lines to be drawn along the tops and bottoms of the objects, and to be sufficiently prolonged, they would appear to meet in a point, as in Fig. 129.

The art which traces objects, with their various degrees of apparent diminution on account of distance, and of foreshortening on account of obliquity of position, is called *perspective*.

2. *The intensity of light, shade, and colour.*—It has been shown, that the intensity of light diminishes rapidly, according to the distance of the body from which it emanates; so that it is only one-fourth as powerful when doubly distant, one-sixteenth when quadruply distant, and so on. This fact is early recognised; and the mind avails itself of it to judge, with much accuracy, of relative distances. It is, however, a pregnant source of optical illusions. In a bright sunshine, mountains appear much nearer to us than when seen through the haze of our *Indian summer*.[1] In a row of lamps along a street, if one be more luminous than the rest, it seems to be the nearest; and, in the night, we incur the strangest errors in judging of the distance of a luminous body. The sky appears nearer to the earth directly above, than it does towards the horizon; because the light from above having to pass only through the atmosphere is but slightly obstructed, whilst a portion only of that, which has to pass through the dense heterogeneous air, near the surface of the earth, arrives at the eye. The upper part of the sky being, therefore, more luminous seems nearer; and, in the same manner, we explain, in part, why the sun and moon appear larger at rising and setting.

The shade of bodies keeps pace with their intensity of light; and accordingly, the shadows of objects near us, are strongly defined;—whilst in the distance they become confused, and the light altogether so faint, that the eye at last sees an extent of distant blue mountain or plain,—"appearing bluish," says Dr. Arnott,[2] "because the transparent air, through which the light must pass, has a blue tinge, and because the quantity of light arriving through the great extent of air is insufficient to exhibit the detail." "The ridge called Blue Mountains," he adds, "in Australia, and another of the same name in America, and many others elsewhere, are not really blue, for they possess all the diversity of scenery, which the finest climates can give; but to the discoverer's eye, bent on them from a distance, they all at first appeared blue, and they have ever since retained the name." As regards the Blue Ridge of America, Dr. Arnott labours under misapprehension. Within a very few miles from the whole of this extensive chain, as well as from a distance, the blue tinge is perceptible, especially

[1] A delightful season, in the southern and western parts of North America more especially, generally occurring in October or November; and having nothing similar to it, so far as we are aware, in any other part of the globe. It is dependent upon some meteorological condition of the atmosphere, and occurs only when the wind is southerly, or from the warmer regions; disappearing immediately as soon as it veers to the north. By some, this phenomenon has been supposed to be caused by the large fires in the western prairies; but the warmth that attends the haze cannot be explained on this hypothesis, independently of other sufficient objections to it.

[2] Op. cit., p. 401.

when the air is dense and clear, soon after the sun has descended behind it; so that the name is as appropriate in the vicinity as it was when "the discoverer's eye was bent on it from a distance."

It is obvious, that without the alternation of light and shade we should be unable to judge, by the eye, of the shape of bodies,—to distinguish a flat circle from a globe; or any of the prominences and depressions, that are every where observable. The universe would seem to be a flat surface, the outlines of which would not even be perceptible; and the only means of discriminating objects would be by their difference of colour. It is partly by attending to the varying intensity of light and shade, that the painter succeeds in representing the near as well as the distant objects in an extensive landscape: those in the foreground are made bold and distinct; whilst the remote prospect is made to become gradually less and less distinct, until it fades away in the distance. This part of his art is called *aerial perspective.*

3. *Convergence of the axes.*—When an object is situate at a moderate distance from us, we so direct the eyes, that if the axes were prolonged they would meet at it. This angle, of course, varies inversely as the distance; so that if the axis be turned to a nearer object, the angle will be greater; if to one more distant, less. By this change in the direction of the axes the mind is capable of judging, to a certain extent, of near distances. A definite muscular effort is required for each particular case; and the difference in the volition necessary to effect it enables the brain to discriminate, precisely in the same manner as it judges of the height of a body, by the muscular action required to carry the axis from one extremity of the object to the other.[1] We have the most satisfactory evidence, that such convergence of the axes is indispensable for judging accurately of distance in near vision. If we fix a ring to a thread suspended from a beam, or attach it to a stand, and endeavour, with one eye closed, to pass a hook, fixed to the extremity of a rod four or five feet long, into the ring, we shall find it impracticable unless by accident or by touching the ring with the rod. The hook will generally be passed on the far or near side of the ring; but if we use both eyes, we can readily succeed. They, however, whose eyes are of unequal power, cannot succeed with both eyes. This is shown by the difficulty experienced by those who have lost an eye. M. Magendie[2] says it sometimes takes a year, before they can form an accurate judgment of the distance of objects placed near the eye. The author has known one or two interesting examples, in which the power was never regained; notwithstanding every endeavour to train the remaining organ.

It need scarcely be said, that the convergence of the axes is no guide to us in estimating objects, which are at such a distance, that the axes are nearly parallel,—as the sun and moon, or any of the celestial luminaries.

4. *Interposition of known objects.*—Another mode of estimating the magnitude or distance of objects is by a previous knowledge of the magnitude or distance of interposed or neighbouring objects; and if no

[1] Sir C. Bell, in Philos. Transact. for 1833.

[2] Précis, &c., i. 88.

such objects intervene, the judgment we form is apt to be inaccurate. This is the reason why we are so deceived as to the extent of an unvaried plain or the distance at which a ship on the ocean may be from us: it is also another cause why the sky appears to us to be nearer at the zenith than it is at the horizon. The artist avails himself of this means of judging of magnitude in his representations of colossal species of the animal or vegetable kingdom, or of the works of human labour and ingenuity,—by placing a well-known object alongside of them as a standard of comparison. Thus, the representation of an elephant or a giraffe might convey but imperfect notions of its size to the mind, without that of its keeper being added as a corrective.

It is in consequence of the interposition of numerous objects, that we are able to judge more accurately of the size and distance of those that are on the same level with us, than when they are either much above or much below us. The size and distance of a man on horseback are easily recognised by the methods already mentioned, when he is riding before us on a dreary plain; the man and horse appearing more diminutive, but, being seen in their usual position, they serve as mutual sources of comparison. When, however, the same individual is viewed from an elevated height, his apparent magnitude, like that of the objects around him, is strikingly less than the reality. Beautifully and accurately is this effect depicted by the great dramatist:—

"How fearful
And dizzy 'tis to cast one's eyes so low!
The crows and choughs, that wing the midway air,
Show scarce so gross as beetles. Half way down
Hangs one that gathers samphire; dreadful trade!
Methinks he seems no bigger than his head.
The fishermen that walk upon the beach,
Appear like mice; and yon tall anchoring bark,
Diminish'd to her cock; her cock a buoy
Almost too small for sight." KING LEAR.

The apparent diminution in the size of objects seen from a height is not to be wholly explained by the foreshortening, which deprives us of our usual modes of judging. It is partly owing to the absence of intervening bodies; and still more perhaps to our not being accustomed to view objects so circumstanced. Similar remarks apply to our estimates of the size and distance of objects placed considerably above us. A cross, at the summit of a lofty steeple, does not appear more than one-fourth of its real size, making allowance for the probable distance; yet a singular anomaly occurs here:—the steeple itself seems taller than it really is; and every one supposes that it would extend much farther along the ground, if prostrated, than it would in reality. The truth, however, is, that if the steeple were laid along the ground, unsurrounded by objects to enable us to form an accurate judgment, it would appear to be much shorter than when erect, on the principles of foreshortening already explained. The cause of this small apparent magnitude of the cross and upper part of the steeple is, that they are viewed without any surrounding objects to compare with them: they, therefore, seem to be smaller than they are; and, seeming smaller, the mind irresistibly refers them to a greater distance. For these reasons, then, it becomes neces-

sary, that figures, placed on lofty columns, should be of colossal magnitude.

It is owing partly to the intervention of bodies, that the sun and moon appear to us of greater dimensions, when rising or setting, although the visual angle, subtended by them, may be the same. "The sun and moon," says Dr. Arnott,[1] "in appearance from this earth are nearly of the same size, viz.:—each occupying in the field of view about the half of a degree, or as much as is occupied by a circle of a foot in diameter, when held one hundred and twenty-five feet from the eye—which circle, therefore, at that distance, and at any time, would just hide either of them. Now, when a man sees the rising moon apparently filling up the end of a street, which he knows to be one hundred feet wide, he very naturally believes, that the moon then subtends a greater angle than usual, until the reflection occurs to him, that he is using, as a measure, a street known, indeed, to be one hundred feet wide, but of which the part concerned, owing to its distance, occupies in his eye a very small space. The width of the street near him may occupy sixty degrees in his field of view, and he might see from between the houses many broad constellations instead of the moon only; but the width of the street afar off may not occupy, in the same field of view, the twentieth part of a degree, and the moon, which always occupies half a degree, will there appear comparatively large. The kind of illusion, now spoken of, is yet more remarkable, when the moon is seen rising near still larger known objects—for instance, beyond a town or a hill which then appears within a luminous circle."

Such are the chief methods by which we form our judgment of the distance and magnitude of bodies;—1st, by the visual angle—2dly, by the intensity of light, shade, and colour—3dly, by the convergence of the axes of the eyes—and 4thly, by the interposition of known objects.

The eye also enables us to appreciate the *motion* of bodies. This it does by the movement of their images upon the retina; by the variation in the size of the image; and by the altered direction of the light in reaching the eye. If a body be projected with great force and rapidity, we are incapable of perceiving it;—as in the case of a shot fired from a gun, especially when near us. But if it be projected from a distance, as the field of view is very extensive, it is more easy to perceive it. The bombs, sent from an enemy's encampment, in the darkness of night, can be seen far in the air for some time before they fall; and afford objects for interesting speculation regarding their probable destination.

To form an accurate estimation of the motion of a body, we must be ourselves still. When sailing on a river, the objects, that are stationary on the banks, appear to be moving; whilst the boat, which is in motion, seems to be at rest. Bodies, that are moving in a straight line to or from us, scarcely appear to be in motion. In such cases, the only mode we have of detecting their motion is by the gradual increase in their size and illumination when they approach us; and the converse, when they are receding from us. If at a distance, and the visual angle between the extreme points of observation be very small, the motion of an

[1] Op. citat.

object will likewise appear extremely slow; hence the difference between a carriage dashing past us in the street, and the same object viewed from a lofty column. A balloon may be moving along at the rate of nearly one hundred miles per hour; yet, except for its gradual diminution in size and intensity of light, it may appear to be at rest; and, when bodies are extremely remote from us, however astonishing may be their velocity, it can scarcely be detected. Thus, the moon revolves round the earth at the rate of between thirty and forty miles a minute—above forty times swifter than the fleetest horse; yet her motion, during any one moment, completely escapes detection; and the remark applies still more forcibly to those luminaries, which are at a yet greater distance from the earth. These are cases in which the body moves with excessive velocity, yet the image on the eye is almost stationary; but there are others in which the *real* motion is extremely slow and cannot be at all observed; as that of the hour-hand of a clock or watch.

It will be obvious, from all the remarks that have been made regarding the information derived by the mind from the sense of sight, that a strictly intellectual process has to be executed, without which no judgment can be formed; and that nothing can be more erroneous than the notion, at one time prevalent, that the method by which we judge of distance, figure, &c., is instinctive or dependent upon an original "law of the constitution," and totally independent of any knowledge gained through the medium of the external senses. It has already been remarked, that metaphysicians may be considered as divided into those, who believe that, without the sense of touch, the eye would be incapable of forming any accurate judgment on these points;—and those who think, that the sense of touch is no farther necessary than as an auxiliary, and that a correct appreciation may be formed by sight alone. Messrs. Molyneux,[1] Berkeley,[2] Condillac,[3] &c., support the former view; MM. Gall,[4] Adelon,[5] &c., the latter.

Of the precise condition of the visual perception during early infancy, we are of course entirely ignorant. So far as our own recollections would carry us back, we have always been able to form a correct judgment of magnitude, distance, and figure. Observation, however, of the habitudes of infants would seem to show, that their appreciation of these points—especially of distance—is singularly unprecise; but whether this be owing to the sense not yet having received a sufficient degree of assistance from touch, or from want of the necessary development in the structure or functions of the eyeball or its accessory parts, we are precluded from judging. The only succedaneum is the information to be obtained from those who have been blind from birth, and have been restored to sight by a surgical operation, regarding their visual sensations. Although in the numerous operations of this kind, which have been performed, it might seem, that cases must have frequently occurred for examining into this question, such is not the fact; and metaphysicians and physiologists have generally founded their observations on the

[1] Locke's Essay on the Human Understanding, book ii. chap. 9.
[2] Essay on Vision, 2d edit., Dublin, 1709.
[3] Traité des Sensations, Part i.
[4] Sur les Fonctions du Cerveau, i. 80, Paris, 1825.
[5] Physiologie de l'Homme, edit. cit., i. 466.

well known case described by Mr. Cheselden.[1] The subject of this was a young gentleman, who was born blind, or lost his sight so early, that he had no remembrance of ever having seen; and was "couched,"—so says Cheselden,—"between thirteen and fourteen years of age." M. Magendie[2] affirms, that there is every reason to believe that the operation was not for cataract, but consisted in the incision of the pupillary membrane. It need hardly be remarked, that Cheselden must be the best possible authority on this subject. "When he first saw," says Cheselden, "he was so far from making any judgment about distances, that he thought all objects whatever touched his eyes (as he expressed it), as what he felt did his skin, and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was in any object that was pleasing to him. He knew not the shape of any thing, nor any one thing from another, however different in shape or magnitude; but upon being told what things were, whose form he before knew from feeling, he would carefully observe, that he might know them again; but having too many objects to learn at once, he forgot many of them; and (as he said), at first he learned to know, and again forgot a thousand things in a day. At first he could bear but very little light, and the things he saw he thought extremely large; but, upon seeing things larger, those first seen he conceived less, never being able to imagine any lines beyond the bounds he saw: the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look bigger."

A much more interesting case, in many respects, than this, which has always appeared to us too poetical, was laid before the Royal Society of London, in 1826, by Dr. Wardrop.[3] It was that of a lady born blind, who received sight at the age of forty-six, by the formation of an artificial pupil. During the first months of her infancy, this lady was observed to have something peculiar in the appearance of her eyes; and, when about six months old, a Parisian oculist operated on both eyes, with the effect of complete destruction of the one, and not the slightest improvement of the other. From this time, she continued totally blind, being merely able to distinguish a very light from a very dark room, but without the power of perceiving even the situation of the window through which the light entered; although in sunshine, or bright moonlight, she knew its direction: she was, therefore, in greater darkness than the boy in Cheselden's case, who knew black, white, and scarlet, apart from each other; and, when in a good light, had that degree of sight, which usually exists in an eye affected with cataract; whilst in this lady the pupil was completely shut up, so that no light could reach the retina, except such rays as could pass through the substance of the iris. After a third operation had been performed for the formation of an artificial pupil, she returned from Dr. Wardrop's house in a carriage, with her eyes covered by only a loose piece of silk. The first thing she noticed was a hackney-coach passing by, when she exclaimed, "What is that large thing that has passed by

[1] Philosophical Transactions, No. 402, p. 477, for 1728; and Anatomy of the Human Body, 13th edit., Lond., 1792.

[2] Précis, &c., i. 95.

[3] Philosoph. Transact., 1826, p. 529.

us?" In the course of the evening she requested her brother to show her his watch, when she looked at it a considerable time, holding it close to her eye. "She was asked what she saw, and she said there was a dark and a bright side; she pointed to the hour of twelve and smiled. Her brother asked her if she saw anything more; she replied yes, and pointed to the hour of six, and to the hands of the watch. She then looked at the chain and seals, and observed that one of the seals was bright, which was the case, being a solid piece of rock crystal." On the third day, she observed the doors on the opposite side of the street, and asked if they were red. They were of an oak colour. In the evening she looked at her brother's face, and said she saw his nose; he asked her to touch it, which she did: he then slipped a handkerchief over his face, and asked her to look again, when she playfully pulled it off, and asked, "What is that?" On the thirteenth day, she walked out with her brother in the streets of London, distinctly distinguishing the street from the foot pavement, and stepping from one to the other, like a person accustomed to the use of her eyes. "Eighteen days after the last operation," says Dr. Wardrop, "I attempted to ascertain, by a few experiments, her precise notions of the colour, size, and forms, positions, motions, and distances of external objects. As she could only see with one eye, nothing could be ascertained respecting the question of double vision. She evidently saw the difference of colours; that is, she received and was sensible of different impressions from different colours. When pieces of paper, one and a half inch square, differently coloured, were presented to her, she not only distinguished them at once from one another, but gave a decided preference to some colours, liking yellow most, and then pale pink. It may be here mentioned, that, when desirous of examining an object, she had considerable difficulty in directing her eye to it, and finding out its position, moving her hand as well as her eye in various directions, as a person, when blindfolded or in the dark, gropes with his hand for what he wishes to touch. She also distinguished a large from a small object, when they were both held up before her for comparison. She said she saw different forms in various objects, which were shown to her. On asking what she meant by different forms, such as long, round, and square, and desiring her to draw with her finger those forms on her other hand, and then presenting to her eye the respective forms, she pointed to them exactly; she not only distinguished small from large objects, but knew what was meant by above and below; to prove which, a figure drawn with ink was placed before her eye, having one end broad and the other narrow, and she saw the positions as they really were, and not inverted [!!]. She could also perceive motions; for when a glass of water was placed on the table before her, on approaching her hand near it, it was moved quickly to a greater distance, upon which she immediately said, 'You move it; you take it away.' She seemed to have the greatest difficulty in finding out the distance of any object; for, when an object was held close to her eye, she would search for it by stretching her hand far beyond its position, while on other occasions she groped close to her own face for a thing far remote from her."

The particulars of this case have been given at some length, inasmuch as they are regarded by Dr. Bostock[1]—and apparently by Dr. Wardrop himself—as strikingly confirmatory of those of Cheselden, than which we cannot imagine anything more dissimilar. It will have been noticed, that, from the very first after the reception of sight, she formed an imperfect judgment of objects, and even of distances, although she was devoid of the elements necessary for arriving at an accurate estimate of the latter,—the sight of both eyes. This was, doubtless, the chief cause of that groping for objects described by Dr. Wardrop. Of forms, too, she must have had at least an imperfect notion, for we find, that on the thirteenth day after the operation, she stepped from the elevated foot-pavement to the street, "like a person accustomed to the use of her eyes."

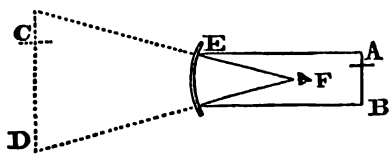
The case is, we think, greatly in favour of the view, that the sight does not require much education to judge with tolerable accuracy of the position, magnitude, distance, surface, and motion of bodies; and that, by a combination of the methods already pointed out, or of some of them, this imperfect knowledge is obtained without the aid of any of the other senses; but is of course acquired more easily and accurately with their assistance, especially with that of touch. What other than visual impressions could have communicated to the mind of Miss Biffin—whose case was referred to under another head—the accurate and minute information she possessed regarding the bodies surrounding her at all distances? Or how does the animal, immediately after birth, acquire its knowledge of distance? We observe the young of certain animals, immediately after they are extruded from the uterus, turn round and embrace the maternal teat; whilst others, as the partridge, follow the mother in a short time after they have burst the shell. The experience required for obtaining an imperfect knowledge of distance, shape, &c., must, therefore, be trifling; although an accurate acquaintance may demand numerous and careful comparisons. This first degree of knowledge is probably obtained, by comparing the visual angle with the intensity of light, shade, and colour,—the more accurate appreciation following the use of the other methods already described. That the convergence of the axes requires education is demonstrated by the case of the infant. It has been remarked, that the eyeballs harmonize instinctively in their parallel motions; but the convergence requires an effort of volition, and it is some time before it can be effected, which is probably the great cause of the mal-appreciation of near distances, that we notice in the infant; whilst it seems to exhibit its capability of judging more correctly of objects, that are somewhat more remote; and where less convergence, and consequently less muscular effort, is necessary.

The numerous *optical illusions*, which we have been compelled to describe in the progress of the preceding remarks, will render it necessary to refer to but few under this head. It has already been said, that we lay it down as a rule, that the progress of light to the eye is

[1] Physiology, 3d edit., p. 703, Lond., 1836. See, also, the case of a gentleman born blind, and successfully operated upon in the eighteenth year of his age, by Dr. J. C. Franz, in Proceedings of the Royal Society, 1840–41, No. 46.

always in a straight line from the luminous object; and, accordingly, if the course of the rays be modified before they reach the organ, we fall into an optical illusion. Such modifications arise either from the reflection or refraction of the rays proceeding from the object that causes the sensation. By reflection of the rays, we experience the illusion caused by mirrors. A ray of light, K C, Fig. 77, falling upon a plane mirror, I J, is reflected back in the same line; but, as we have seen, the object does not appear to be at K, but at E. Again, a ray of light, proceeding obliquely from B, and impinging on a plane mirror at C, is reflected in the direction of C A; but to the eye at A, the object B appears to be at H, in the prolongation of the ray that reaches the eye.

Fig. 130.

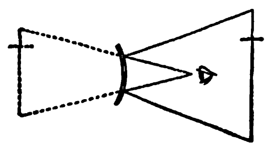


Concave Mirror.

If the mirror be concave, the object appears magnified, provided the light from the upper part of the object, as A B, Fig. 130, be reflected to an eye at F, and that from the lower part of the object meet the other at this point. To an eye so placed, the object appears magnified and seems to be at C D, or in the prolongation of the rays which fall upon the cornea. If the mirror be convex (Fig. 131), for like reasons, the cross will seem to be smaller.

The cornea constitutes a mirror of this class, in which we have an accurate miniature representation of objects.

Fig. 131.



Convex Mirror.

Rays that are refracted in passing through different media, give rise to visual illusions. We have seen, that the ray from an object at F, Fig. 77, in the pool of water, I J, does not proceed into the air in the direction of F C O, but in that of the line F C A; and if we suppose the eye to be placed at A, the object will not be seen at F, but will appear to be at *f*; the pool will, consequently, appear shallower than it really is, by the space at which *f* is situate above the bottom. We can now understand why rivers appear less deep than they are, when viewed obliquely; and why the lower end of a pole, immersed in water, should, when seen obliquely, appear to be bent towards the surface. In shooting fish in the water, or in attempting to harpoon them, this source of error has to be corrected. Birds, too, that live upon the inhabitants of the water, have to learn, from experience, to obviate the optical illusion; or to descend perpendicularly upon their prey, in which direction, as we have seen, no refraction takes place. Similar remarks apply to fish that leap out of the streams to catch objects in the air. The *Chætodon rostratus*, about six or eight inches long, frequents the sea-shores in the East Indies: when it observes a fly sitting on the plants that grow in shallow water it swims to the distance of five or six feet, and then, with surprising dexterity, ejects out of its tubular mouth a single drop of water,

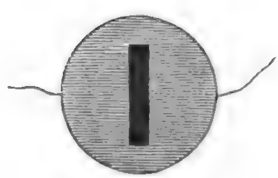
which never fails to strike the fly into the sea, where it soon becomes its prey.[1] Hommel—a Dutch governor—put some of these fish into a tub of water, and pinned a fly on a stick within their reach. He daily saw the fish shoot at the fly, and with such dexterity, that they never failed to hit the mark.[2] Pallas describes the *Sixena jaculatrix* as securing flies by a similar contrivance.[3]

If the light, before reaching the eye, passes through bodies of a lenticular shape, it undergoes modifications, which have given occasion to the formation of useful instruments devised for modifying the sphere of vision. If the lens be double convex, the body, seen through it, appears larger than it is, from the illusion, so often referred to, that we always refer the object in the direction of the line that impinges upon the retina. The object, consequently, appears to be greatly augmented. (See Fig. 83.) For the same reasons an object seems smaller to the eye at A, Fig. 80, when viewed through a double concave lens. Again, if the light, before reaching the cornea, be made to pass through a diaphanous body, which is itself coloured, and consequently allows only the rays of its own colour to traverse it, the object is not seen of its proper colour, but of that of the transparent body.

An impression of light continues to affect the retina for some time after the impression has ceased, certainly for the sixth part of a second.[4] If, therefore, a live coal be whirled round, six or seven times in a second, it will seem to be a continuous circle of fire. It is owing to this circumstance, that meteors seem to form a line of light—as in the case of the falling star; and that the same impression is conveyed by a sky-rocket in its course through the air. We have an elucidation of the same fact in the instrument or toy—called, by Dr. Paris, *thaumatrope*—which consists of a circle, cut out of a card, and having two silken strings attached to opposite points of its diameter: by twisting these with the finger and thumb the card may be twirled round with considerable velocity. If we make on one side a black stripe as in the marginal figure 132, and on the other side one at right angles to it, Fig. 133, and cause the card to revolve rapidly, we shall see a cross. And if on one side

Fig. 132.

Fig. 133.



Thaumatrope.

of the card a chariot is drawn—and on the other a charioteer, and the card be twirled round six or seven times in a second, the charioteer will be seen in the chariot,—the duration of the impressions on the retina being

[1] Fleming's Philos. of Zoology, i. 195. [2] Philos. Trans., liv. 89.

[3] Philos. Trans., lvi. 186; also, Mr. Sharon Turner's Sacred History of the World, Amer. edit., i. 205, New York, 1832.

[4] D'Arcy, Mémoires de l'Académie des Sciences, p. 439, Paris, 1765; and Plateau, Annales de Chimie, &c., vol. lviii. p. 401.

such as to cause the figures, drawn on both sides of the card, to be seen at nearly the same time. The phantasmascope, phenakistiscope and anorthoscope, act upon similar principles.[1]

It is by accurate attention to various optical illusions, and to the laws of the animal economy on which they are founded, that many of them can be produced in the arts at pleasure. Painting is, in truth, little more than depicting on canvass the various optical errors, which we are habitually incurring.

To conclude:—the sense of sight differs materially in the scale of animals: in few is the organization more perfect or the function better executed than in man. Situate at the upper and anterior part of the body, the organ of vision is capable of directing its regards over a large extent of surface: the axes of the two organs can be converged upon objects in various situations, which cannot be done by many animals; and they are very movable under the domination of a muscular apparatus of admirable arrangement. Still, the eye is not as delicately organized as in some animals, which are capable of seeing objects at a distance that would be totally beyond the reach of the visual powers of man.

Like the other senses, sight can be exerted *actively* and *passively;* hence the difference between simply *seeing*, and *looking*. In the latter, the eye is directed to the object by the proper muscles; and it is not improbable, that the nerve may be aroused to a more accurate and delicate reception of impressions, as we have reason for believing is the case in the other senses. Like them, it admits of great improvement by education. The painter, and the worker in colours are capable of nice discrimination, and detect the minutest shades of difference with great facility. In savage life, where the tracks or marks through the almost interminable forests, or over the pathless wilds, are the only guides, the greatest acuteness of vision is necessary; and, accordingly, we find the North American Indian, in this respect, eminently distinguished. The mariner, too, accustomed to look out for land, or for a hostile sail, detects it in the distant horizon long before it can be perceived by the landsman, and appreciates its distance and course with signal accuracy,—education, in this case, not only communicating to his eye facility in being impressed, but improving the intellectual process, by which the estimation of distances is arrived at.

ADDITIONAL SENSES.

The five senses constitute so many special nervous systems, each concerned in its appropriate function; and, although conveying ideas of the external world to the brain, and connected with that organ, they are to a certain extent independent of it. The generality of physiologists admit these five only; but some have suggested others, differing, in general, from the five, in having no organ at the surface of the body exclusively concerned in the function. Buffon regarded as a *sixth sense* the intense sensation experienced during the venereal act; but this can

[1] Müller, Principles of Physics and Meteorology, p. 310, Philad., 1848.

only be esteemed a peculiar variety of tact in the mucous membrane of the genital organs,—differing from ordinary tact in those parts, in requiring in both sexes a special condition of the membrane; and, in the male, one such, that the sperm, when excreted, shall make the necessary impression upon it; and, consequently, appertaining to both the external and internal sensations;—the state of the membrane being referable to the latter, and the effect of the contact of the sperm to the former. Some have spoken of a *sense of heat and cold*:—this has been referred to under the head of tact;—others of a *muscular sense*, by which we acquire a knowledge of the motions that muscular contractions give rise to, and learn to apportion the effort to the degree of effect to be produced. Animal magnetizers have suggested a sixth sense, to which man owes the capability of being acted upon by them: but this is supposititious, and the facts admit of a more ready and satisfactory explanation. A *sense of hunger* has been described as situate at the upper orifice of the stomach:—a *sense of thirst* in the œsophagus, and a *pneumatic sense* in the lungs; but these are rather internal sensations.

The German physiologists have suggested another sense, which they term *cœnæsthesis*, Gemeingefühl, Gemeinsinn, Korpergefühl, Lebenssinn, Individualitätssinn, and Selbstgefühl ("common feeling, common sensation, bodily feeling, feeling of life, sense of life, sense of individuality, and self-feeling"). This is not seated in any particular part of the body, but over the whole system; hence termed "common." It is indicated by the lightness and buoyancy, which we occasionally experience, apparently without any adequate cause; as well as by a sense of lassitude and fatigue unconnected with muscular action or disease. To it, likewise, belong the involuntary shuddering, glow, and chilliness, experienced under like circumstances. It is manifestly one of the numerous internal sensations, felt by the frame, and every portion of it, according as they are in a perfect state of health, or labouring under irritation or oppression; but can scarcely be regarded as an additional or sixth sense.[1]

It has been supposed, that certain animals may possess other senses than the five. Of this we can have no positive evidence. We are devoid of the means of judging of their sensations; and if we meet with an additional organ, which seems adapted for such a purpose, we have nothing but conjecture to guide us. Under the sense of touch it was said, that the bat is found to be capable of avoiding obstacles placed in its way intentionally, when the eyes, nostrils, &c., have been closed up; and that it readily returns to the holes in caverns to which it is habituated. Spallanzani supposed that this was owing to its being possessed of a sixth sense. We have seen, that the circumstance is explicable by unusual delicacy of one of the external senses.

Again; the accuracy with which migratory animals return to their accustomed haunts, has given rise to the notion of a *sense of locality*.

Quadrupeds, the ape not excepted, have two bones in the face, in

[1] Purkinje, art. Cœnæsthesis, in Encycl. Wörterb. der Medicinisch. Wissenschaft. viii. 116, Berlin, 1832; and Müller's Elements of Physiology, by Baly, P. v. p. 1087, London, 1839. See, also, E. H. Weber, art. Tastsinn und das Gemeingefühl, in Wagner's Handwörterbuch der Physiologie, 22ste Lieferung, s. 562, Braunschweig, 1849.

addition to those found in man. These contain the roots of the dentes incisores, when such are present; but they also exist in animals that are destitute of teeth. They are termed *ossa intermaxillaria*, *ossa incisoria*, and *ossa labialia;* and are situate, as their names import, at the anterior part of the jaw, and between the ossa maxillaria or jaw bones. Jacobson[1] considers them to be an organ of sense, as they communicate with the exterior, and are largely supplied with vessels and nerves. Accordingly, this has been esteemed a sensitive apparatus, connected with the season of love in animals; and, by other naturalists, as a sense intermediate between those of taste and smell, and intended to guide the animal in the proper selection of food. It need hardly be said, that this is all imaginary.

M. Adelon,[2] it was remarked, makes two divisions of the external sensations:—those that convey information to the mind; and those that do not. The former have engaged attention; the latter will not occupy us long. They comprise but two—*itching* and *tickling*. Both of these occur in the skin and mucous membranes, and near the communication of the latter with the skin; or, in other words, near the termination of the outlets which they line. *Itching*, however, is not always an external sensation,—that is, not always caused by the contact of a body external to it. It frequently arises from an altered condition of the organic actions of the part in which it is experienced, as in cutaneous affections; in itching at the nose produced by irritation in the intestinal canal; itching of the glans penis in cases of calculi of the urinary bladder, &c.; but commonly the sensation is caused by an extraneous body, and we are irresistibly led to scratch, no matter how it may be caused. When it arises extraneously, it can generally be readily allayed; but, when dependent upon a morbid condition of the texture of the part, it becomes a true disease, and the source of much suffering. If the itching be accompanied with a feeling of motion, or of purring in the part, it is called *tingling*. This kind of purring often occurs without itching.

Tickling or *titillation* is always caused by the contact of some extraneous substance; and is therefore a true external sensation. Although occurring in the skin, and in the commencement or termination of the mucous membranes, all parts are not equally susceptible of it; and some,—as the lining membrane of the genital organs,—are only, or chiefly so, under special circumstances. The sides, palms of the hands, and soles of the feet, are the most sensitive in this respect; not, perhaps, because the nerves are more numerous in those parts, but because, owing to thinness or suppleness of skin, or to other inappreciable circumstances, they are more susceptible of this kind of excitation. We find, too, that individuals differ as much as the parts of the body do in this respect;—some being *not ticklish*, or incapable of being thrown into the spasm, which the act,—nay, even the threatening of the act,—produces in others. Cases are on record, in which prolonged titillation has caused general convulsions, and even death. Le Cat[3] terms

[1] Annales du Musée, xviii. 412.
[2] Physiologie de l'Homme, 2de édit., i. 481, Paris, 1829.
[3] Traité des Sens, Paris, 1767.

it an hermaphroditic sensation, inasmuch as, whilst it excites laughter, it is insupportable; and, consequently, seems to be intermediate between pleasure and pain.

c. *Internal Sensations.*

The external sensations make us acquainted with the universe surrounding us; and convey to the mind a knowledge of every thing that can be, in any manner, inservient to our necessities. Such necessities have, however, to be suggested to the mind, before it reacts through the aid of the organs of prehension or otherwise on external bodies, and this is accomplished by the *internal* or *organic sensations.*

Without the intervention of an external cause, every organ of the body is capable of transmitting to the encephalon a number of different impressions, many of which impel the organs to acts that are necessary not only for the preservation of the individual and of the species, but also for the perfect developement of the faculties. Such are the sensations of hunger and thirst; the impulse that leads to the union of the sexes; and the feeling we have of the necessity for intermission in the exercise of the muscles, and the intellect. They have been divided into three species by some physiologists;—the *first* arousing, or giving impulse to, the action of organs, and warning the brain of the different necessities of the system. They have been called *wants* or *instinctive desires.*[1] Such are hunger, thirst, the desire to evacuate the urine and fæces; that of respiration, the venereal appetite (*le génésique*, *amour physique*), *accouchement*, &c. They belong to those that arise, when it is necessary the organs should act.—The *second* occur during the action of organs. They are often obscure, but sometimes acute. Amongst these are the impressions accompanying the different excretions,—as of the sperm, urine, &c. (although, as we have seen, these partly belong to the external sensations); the impressions that warn us of our partial or general movements, of the progress of digestion, and of intellectual labours. The *last* succeed to the action of organs, especially when such action has been too long continued; hence the inward feeling of *fatigue* after too long exertion of the functions of the senses, of the intellectual and moral faculties, and of the organs of muscular motion; the *necessity of repose* after prolonged muscular exertion; and of *sleep*, to recruit the nervous system, and to fit it for the exertions it has to make during the waking condition.

The mode in which these sensations are effected is analogous to that of the external sensations. There is an *impression* on the part to which the sensation is referred; an action of *perception* accomplished by the encephalon; and one of *transmission*, executed by a nerve passing between the two. The last two actions are probably executed in the same manner as in the external sensations. The first, or the mode in which the impression is effected, and the character of the impression itself, are more obscure. In the external sensations, we can refer the impression to a known irritant,—special in some of the senses:

[1] Adelon, art. Besoins, in Dict. de Médecine, i. 367, Paris, 1821; and Physiologie de l'Homme, i. 482.

—more general in others. We know, that light impresses the retina;—aerial undulations the acoustic nerve, &c.; but, in the internal sensations or *sentiments*, as some of the French writers term them, the source of the irritation is in some modified action of the part itself, in the very tissue of the organ, and hence the result is said to be *organic*. In the internal sensation of hunger, for example, the impression is engendered in the organ,—how, we know not,—is thence conveyed to the brain, and the sensation is not effected until the latter has acted. The same may be said of all the internal sensations. They differ, in other respects, also, from the external. Whilst the latter may be entirely passive, or rendered active by volition, without either action being the cause of particular pleasure or inconvenience, the former are little influenced by volition. Constituting the wants—the instinctive desires—which impel to acts, that are necessary for the preservation and full developement of the individual and of the species, such independence is of course essential. On many of them, however, habit or accustomed volition has a certain degree of influence; and they can unquestionably be augmented or moderated by licentious indulgence or restraint. The influence of habit is exemplified by the regularity with which the appetite returns at stated intervals; and by the difference between that of the gourmand and of the temperate individual. It is most strikingly evidenced, however, in its influence over the moral wants; which may even spring up from social indulgence, and hence are not instinctive or organic. We are every day compelled to witness the striking difference between the individual who practises restraint upon his wants, and the libertine, who, like the animals surrounding him, gives unbridled sway to his natural and acquired appetites.

All the internal sensations, when satisfied or responded to in moderation, communicate a feeling of pleasure; but if resisted, pain results. If hunger be prolonged, there is a general feeling of uneasiness, which rapidly abates after food is received into the stomach; but if satiety be produced, uneasiness follows; and this applies to all the appetites or wants. The special internal sensations will engage us, when the functions to which they belong fall under consideration. Like the external sensations, they must, of course, administer to the intellect, to an extent which will be seen hereafter. Their influence and nature were entirely neglected until of comparatively late years, when attention was directed to them chiefly through the labours of MM. Cabanis[1] and of Destutt-Tracy;[2] and they now form subjects for interesting speculation, with the metaphysician more especially.

The *morbid sensations* belong more particularly to pathology; a brief notice of them will consequently be all that is necessary here. They are comprised under the term *pain*. In its enlarged signification, this word, as is well known, means every uneasy or disagreeable sensation or moral affection;—thus including sadness, anger, terror, as well as the painful impressions felt in the extremities or trunks of

[1] Rapport du Physique et du Morale de l'Homme, tom. ii., Paris, 1802.
[2] Elémens d'Idéologie, 2de édit., Paris, 1804.

the nerves. It is the latter only—or *physical pain*—that concerns us at present. Like every other sensation, although it may be referred exclusively to the part impressed, pain requires the intervention of the encephalon; for if the nerves, proceeding from a part to that organ, be cut, tied, compressed, or stupefied by narcotics; or if the action of the brain itself be blunted from any cause, as by the use of opium, ether, or chloroform, or by any compression, accidental or other, the sensation is no longer experienced. We can thus understand why pain is felt less during sleep; and the astonishing cases of resistance to pain, witnessed in the lunatic, and in religious or other enthusiasts who have been subjected to bodily torture. An opposite condition of the nervous system is the cause of the great sensibility to impressions in the nervous and hysterical.

It is obvious, that pain may be either an external or internal sensation, according as the cause of irritation is extraneous, or seated in the tissue of organs; and that it must vary considerably, both as regards the precise irritant, and the part affected; hence the difference between the pain caused by a burn, and that by a cutting instrument; and the immense variety of pains to which the human frame is subject, and the attentive study of which is so indispensable to the pathologist.

So much for the sensations. These, we have seen, are innumerable, for each sense is capable of myriads of different impressions. We now pass to the consideration of those functions that enable man—although worse provided with means of defence and offence than the beasts surrounding him, and possessing no covering to protect him from the summer's heat or the winter's cold—to provide himself means of defence; to render the animals around him subservient to his use; to cover his nakedness, and protect himself against atmospheric changes; to devise mechanical arts; to fathom the laws, that govern the bodies by which he is surrounded, and to establish himself undisputed master of the earth.

MENTAL FACULTIES.

The external senses convey to the brain the different impressions made upon them by surrounding bodies; but, of themselves, they would be unable to instruct the mind regarding the universe. It is necessary, that the brain should act before any perception of them can exist. The *mental faculties*, in other words, convert the impressions into ideas. The internal sensations, on the other hand, consist, as we have seen, of the numerous wants and appetites necessary for the preservation of the individual, and the species. In addition to these, man possesses another series of faculties, which influence his character and disposition, and direct his social existence: these are the *affective* or *emotive faculties* or *faculties of the heart*. The study of these different mental and moral phenomena constitutes what has been called *psychology*,—so termed from an idea, that they are exclusively dependent upon the mind. The notion was, at one time, universal, and hence the appellation *metaphysician*, applied to such as were considered to proceed in their investigations beyond what was physical, material, or corporeal.

There is no subject, which has given occasion to so much excitement and controversy, as that of the connexion of the mental faculties with the encephalon. "It has unfortunately happened," says Dr. Bostock,[1] "that this subject, which is one of great interest and curiosity, has seldom been viewed with that philosophical spirit which should always direct our investigations, and by which alone we can expect to arrive at truth. It is admitted, that certain errors may be so interwoven with our accustomed associations, on topics connected with morals and religion, as to render it doubtful, on some occasions, how far we ought to attempt their removal; but if this concession be made on the one hand, it is incumbent upon us, on the other, not to inflame the prejudices, which may exist on these topics, but to use our endeavours to correct all undue excitement, and thus to bring the mind into that tranquil state, which may enable it to receive truth without fear of injury." In such a spirit ought every discussion on the subject to be conducted; and in such a spirit will the few remarks that follow be offered.

The chief opinions, which have been indulged on the subject are,—1st. That all the mental phenomena are immaterial, and the exclusive product of the mind. 2dly. That the sentient principle within us requires the intervention of an organ, through which it acts; in other words, that mind is a principle superadded to organization; and 3dly. That where there is no organization there is no perception:—that wherever an organized structure, like the brain, exists, perception exists; that where the organization is imperfect, perception is imperfect; where the organization is sound and vigorous, perception is clear and vigorous; where it is impaired, perception is impaired; and that when organization ceases perception ceases also. This last view is *materialism*. It supposes, that a certain condition of matter is capable of thinking, reasoning, and understanding.

The doctrine,—that our intellectual and moral acts are superadded to organization, and that there is an organ concerned in their manifestation, is the one embraced by the generality of physiologists, and is most consistent with reason and analogy: it is but justice, however, to admit, that the views of those, who consider that a certain organization produces thought, are not deserving of the anathemas that have been directed against them on the score of irreligion. The charge would rather apply to those who doubt the power of Omnipotence to endow matter with such attributes. Were the mental and moral phenomena the exclusive products of the immaterial principle within us, they would hardly form subjects for physiological inquiry. That they are allied to organization is inferred for the following reasons. As they constitute so many functions, were they not provided with an organ or organs, they would form so many exceptions;—each of the sensations requiring an organ for its accomplishment. Again, our inward feeling induces us to refer them to a particular part of the frame: whilst thought appears to be effected within the head, the chief expressions of the passions are felt in the region of the heart or stomach. The faculties, moreover, are not the same in every individual. One

[1] Physiology, 3d edit., p. 744, Lond., 1836.

man is a poet; another a mathematician; or one is benevolent, another cruel. If these faculties were the exclusive product of the mind, and of course not to be ascribed to diversity of organization, we should have to admit, that each individual has a different immaterial principle, and of course, that there must be as many kinds as there are individuals. Lastly. The faculties vary in the same individual according to circumstances. They are not the same in the child as in the adult; in the adult as in one advanced in life; in health as in disease; in waking as in sleep. During an attack of fever they become temporarily deranged; and are permanently so in all the varieties of insanity.[1] These facts are inexplicable under the doctrine, that they are the exclusive product of the mind or immaterial principle. An immaterial or spiritual principle ought to be immutable; yet we should have to suppose it capable of alteration; of growing with the growth of the body, and of becoming old with it; of being awake or asleep; sound or diseased. All these modifications must be caused by varying organization—of the brain in particular.

We may conclude, then, that the intellectual and moral faculties are not the exclusive product of the mind; that they require the intervention of an organ; and, that this organ is the encephalon, or a part of it —the cerebrum or brain—is announced by many circumstances. In the *first* place, they are phenomena of sensibility, and hence we should be disposed to refer them to a nervous organ; and, being the most elevated phenomena of the kind, to the highest of the nervous organs. In the *second* place, inward feeling impels us to refer them thither. We not only feel the process there, during meditation; but the sense of fatigue, which succeeds to hard study, is felt there likewise. The brain, again, must be in a state of integrity, otherwise the faculties are deranged; or, for the time, abolished. In fever, it becomes affected directly or indirectly, and the consequence is, perversion of the intellect, in the form of delirium. If the organ be more permanently disordered, as by the pressure of an exostosis or tumour, or by some alteration in its structure or functions—less appreciable in its nature—insanity, in some form, may be the result.

In serious accidents to the encephalon, we observe the importance of the cerebrum to the proper exercise of the mental faculties clearly evinced. A man falls from a height, and fractures his skull. The consequence is, depression of a portion of bone, which exerts a degree of compression upon the brain; or extravasation of blood from some of the encephalic vessels attended with similar results. From the moment of the infliction of the injury, the whole of the mental and moral manifestations are suspended, and do not return until the compressing cause is removed by the operation of the trephine. M. Richerand cites the case of a female, who had a portion of the brain accidentally exposed, and in whom it was found, that pressing on the brain completely suspended consciousness, which was not restored until the pressure was removed. A similar case occurred to Professor Wistar; and another is related by

[1] Adelon, art. Encéphale, Dict. de Médecine, vol. vii.; and Physiologie de l'Homme, tom. i. edit. cit.

M. Lepelletier.[1] A patient of a M. Pierquien had an extensive caries of the os frontis, with perforation of the bone, which exposed the brain covered by its membranes. When she slept soundly, the organ sank down; when she dreamed, or spoke with feeling, turgescence and marked oscillations were perceptible; when the brain was pressed upon, she stopped in the middle of a sentence or a word, and when the pressure was removed, she resumed the conversation, without any recollection of the experiment to which she had been subjected. An important difference in the effect is, however, noticed in such cases according to the suddenness or tardiness with which the pressure is made. Whilst a sudden compression suspends the intellectual and moral manifestations for a time; slow pressure, produced by the gradual formation of a tumour, may exist without exhibiting, in any manner, the evidences of its presence. Accordingly, the anatomist is at times surprised to discover such morbid formations in the brains of persons who have never laboured under any mental aberration.

A negative argument in favour of this function of the brain has been deduced from the fact, that disease of other portions of the body, even of the principal organs, may exist and pass on to a fatal termination, leaving those faculties almost unimpaired. Such is proverbially the case with phthisis pulmonalis; the subject of which may be flattering himself with hopes never to be realized, and devising schemes of future aggrandizement and pleasure until within a few hours of his dissolution.

The intellectual faculties differ in each individual, and vary materially with the sex. The brain is, in all these cases, equally different. Much may depend upon education; but it may, we think, be laid down as an incontrovertible position, that there is an original difference in the cerebral organization of the man of genius and of him who is less gifted; and that, as a general rule, in the former the brain is much more developed than in the latter. Whilst the brain of the man of intellect may measure from nineteen to twenty-two inches in circumference, that of the idiot frequently does not exceed thirteen, or is not greater than in the child one year old. It was an ancient observation, that a large development of the anterior and superior parts of the head is a characteristic of genius; and, accordingly, we find, that all the statues of the sages and heroes of antiquity are represented with high and prominent foreheads. In the older poets, we meet with many evidences, that the height of the forehead was regarded as an index of the intellectual or moral character of the individual. Thus Shakspeare:

> "We shall lose our time,
> And all be turn'd to barnacles, or to apes,
> With foreheads villanous low."
>
> CALIBAN, in "TEMPEST."—Act iv.

And again:—

> "Ay, but her forehead's low, and mine's as high."
>
> JULIA, in the "TWO GENTLEMEN OF VERONA."—Act iv.

The relation between the size of the head and the mental manifestations has, indeed, interwoven itself into our ordinary modes of speech.

[1] Physiologie Médicale, &c., iii. 242, Paris, 1832.

"Let it not be believed," says a distinguished writer,[1] "an affair of accident, that a head of considerable dimensions is found, from time to time, to coincide with a distinguished genius. Although the *amour propre* may object, the law is general. I have neither met in antiquity, nor in modern times a man of vast genius, whose head ought not to be ranged in the latter class, which I have just established, especially if attention be paid to the great developement of the forehead. Look at the busts and engravings of Homer, Socrates, Plato, Demosthenes, Pliny, Bacon, Sully, Galileo, Montaigne, Corneille, Racine, Bossuet, Newton, Leibnitz, Locke, Pascal, Boerhaave, Haller, Montesquieu, Voltaire, J. J. Rousseau, Franklin, Diderot, Stoll, Kant, Schiller, &c."

Yet we are not always accurate in estimating the size of the brain from the developement of the head. Dr. Sewall[2] has clearly shown, that skulls of the same dimensions, as measured by the craniometer, differ largely as to the quantity of cerebral substance, which they are capable of containing. With the assistance of Dr. Thomas P. Jones, of Washington, and of Professor Ruggles, of the Columbian College, he instituted various experiments. In the first series, he ascertained the volume of each skull, brain included: in the second series, the volume of the brain alone or the capacity of the cerebral cavity; and in order to render the difference in capacity more obvious, the volume of each skull, brain included, was reduced to the dimensions of 70 fluidounces. The results of the experiments on five skulls, delineated in the plates of Dr. Sewall's work, were as follows:—

	Volume of Skull, Brain included.	Volume of Brain.
Plate II.	70 oz.	56·22 oz.
III.	do.	51·72
IV.	do.	46·21
V.	do.	34·79
VII.	do.	25·33

In two of these skulls, consequently, of the same external dimensions, there was a difference in the volume of brain of 31·89 oz. Dr. Sewall infers from his observations, that no phrenologist, however experienced, can, by any inspection of the living head, ascertain whether a person has a skull of one inch or one-eighth of an inch in thickness; or whether he has 56·22 ounces of brain, or only 25·33 ounces.

To the view, that the mental capacity is in a ratio with the size of the brain there must be numerous exceptions; for, independently of bulk, there may obviously be an organization productive of results, in which the largely developed organ may be greatly deficient. Size is only one of the elements of activity of an organ. "Whilst there is an evident connexion," says a recent writer,[3] "between a large *quantity* of cerebral matter, and a highly developed intellect, the *quality* of the mind and that of the brain-substance may also be supposed to have a close relation to each other. In great power of action a *large* muscle is needed, but for vigorous and well-adjusted muscular movement a cer-

[1] Gall, Sur les Fonctions du Cerveau, ii. 342, Paris, 1825.
[2] An Examination of Phrenology, in Two Lectures, 2d edit., p. 66, Boston, 1839.
[3] Todd and Bowman, The Physiological Anatomy and Physiology of Man, p. 262, Lond., 1845.

tain *quality* of fibre is also necessary to give full scope to the nervous power. It is impossible to determine what the peculiarity in quality is, but some idea of the great influence which it may possess in the exercise of the two great vital forces, the *muscular* and *nervous*, may be gained from comparing the energy and action of a well-bred horse, with one of those, which, in the language of the turf, shows little or no breeding. The actual amount of muscular or nervous fibre may be the same in both, or it may be less in the horse of good breeding than in the other, yet the former does his work and endures fatigue better."

The difference between the *moral* of the male and the female is signal; and there is no less in the shape of the encephalon in the two sexes. Observation, not only by anatomists but by sculptors and painters, shows, that the superior and anterior parts of the brain are less developed in the female, whose forehead is, therefore, as a general rule, smaller; whilst the posterior are larger. In the system of Gall, the anterior and superior parts are considered to be connected with the intellectual manifestations, which are more active in man; whilst the posterior are concerned in the softer feelings, which predominate in the character of the female. The mental and moral faculties vary also, in the same individual, according to age, health, and disease; and in the waking and sleeping state. In all these conditions, we have reason to believe the state of the encephalon is as various. The anatomist notices a manifest difference between its organization in the infant and in the adult or aged. Like the other organs of the body, it is gradually developed until the middle period of life; after which it decays with the rest of the frame. Our acquaintance with the minute organization of the body does not enable us to say on what changes these differences are dependent. We see them only in their results. By the minutest examination of the special nerves of sense we are incapable of saying, why one should appreciate the contact of sapid bodies, another that of light, &c. During sleep, again, in which the functions of the brain are more or less suspended, the condition of the organ is modified; and mania or delirium probably never occurs without the physical condition of the brain having undergone some change, directly or indirectly. It is true, that, on careful examination of the brains of the insane, it has often happened, that no morbid appearance has presented itself; but the same thing has been observed on inspecting those who have died of apoplexy or paralysis, in which not a doubt is entertained that the cause is seated in the encephalon, and that it consists in a physical alteration of its tissue. These are a few of the cases which make us sensible of the limited nature of our powers of observation. They by no means encourage, in the most sceptical, the belief, that the tissue of the organ is not implicated. The investigations of the morbid anatomist, consequently, afford us few data on which to form our opinions on this subject.

The effect of intoxicating substances is mainly exerted on the brain. When taken in moderation, all the faculties are excited; but if pushed too far, the intellectual and moral manifestations become perverted. This can only be through their action on the cerebral organ. We can thus understand, how regimen may cause important modifications

in the brain. Climate has probably a similar influence; hence, the difference between the characters of different nations and races. The skull of the Mongol is different from that of the Kelto-Goth or of the Ethiopian; and the brain, as well as its functions, exhibits equal diversity.

Again, it has been argued, that the facts noticed in the animal kingdom are in favour of the brain being the organ concerned in the mental manifestations; that, if each animal species has its own psychology, in each the encephalon has a special organization; and that in those which exhibit superior powers, the brain is found large, and more complicated. To a great extent this is true. Nothing, indeed, seems more erroneous than the notion, that even sensibility to pain is equal in every variety of the animal creation. As we descend in the scale, the nervous system is found becoming less and less complicated; until ultimately it assumes the simplest *original* character, which has laid the foundation for one of the divisions of Sir Charles Bell's system; and although it is impossible to change places with the animal, we have the strongest reasons for believing, that the sensibility diminishes as we descend; and that the feeling, expressed by the poet, that the beetle, which we tread upon—

> "In corporal sufferance finds a pang as great
> As when a giant dies"—

however humane it may be, is physiologically untrue. The phenomena in favour of this view that present themselves to the naturalist are numerous and interesting; and afford signal evidence of creative wisdom in endowing the frames of those beings of the animal kingdom, that are most exposed to injury and torture, with a less sensible organization. The frog continues sitting, apparently unconcerned, for hours after it has been eviscerated; the tortoise walks about after having lost its head; and the divisions of the polypus, made by the knife, form so many distinct animals. Redi removed the whole of the brain of a common land tortoise: the eyes closed to open no more; but the animal walked as before,—groping, as it were, its way for want of vision. It lived nearly six months. All have noticed the independence of the parts of a wasp, after the head has been severed from the body. It will try to bite, and, for a considerable time, the abdomen will attempt to sting.* An illustrative instance of the kind occurred to Dr. Harlan.[1] He cut off the head of a rattlesnake; and, grasping the part of the neck attached to the head with his finger and thumb, the head twisted itself violently, endeavouring to strike him with its fangs. A live rabbit was presented to the head, which immediately plunged its fangs deep into the animal; and when the tail of the snake was laid hold of, the headless neck was bent quickly round as if to strike the experimenter. The experiments of Dr. Le Conte,[2] of Savannah, Georgia, and of Dr. Bennet Dowler,[3] of New Orleans, on the Alligator—*crocodilus lucius*—exhibit like results, and would lead to the inference, that in that animal, phenomena essentially resembling those which in the

[1] Medical and Physical Researches, p. 503, Philad., 1835.
[2] New York Journal of Medicine, Nov. 1845, p. 335.
[3] Contributions to Physiology, New Orleans, 1849.

upper classes of animals are referable to the encephalon, may be more diffused in their origin. In one experiment by the latter gentleman, and Dr. Young, aided by Mr. Barbot, the head of the animal, for more than an hour after decollation, exhibited that it possessed sensation, perception, vision, passion, and voluntary motion. "It saw its enemies; opened its mouth to bite at the proper time; and nictated when a foreign body approached the eye;" and for three or four hours the headless trunk, during extensive mutilations by two operators, "manifested, in a still higher degree, sensation, intelligence, definite, well-directed muscular actions. There was, as usual, a complete loss of progressive or forward motion. The test used to elicit sensation and voluntary movements were pinching, puncturing and burning. Its sensibility and motions appeared to be nearly as acute, quick and varied as in the unmutilated animal. The direction of the limbs was not such as could be deemed habitual, as in walking and swimming. Some of these motions are of difficult execution in the entire animal from its anatomical conformation, such as reaching up between the shoulders or hips to remove an irritant."

In another experiment performed in the presence of Drs. Cartwright, Smith, Nutt, Powell, Hire, Mr. Barbot, and Professor Forshey—in which decollation was practised with a dull hatchet, and, in consequence, the hemorrhage was not great, although considerable—Dr. Dowler carried the handle of a knife towards the eye, to ascertain whether it would wink; "whereupon the ferocious, separated head" sprang up from the table with great force at him, passing very near his breast, which received several drops of blood; and then alighted upon the floor from six to eight feet distant from its original position. It missed him because he was standing at the side, and not in front of the head. "For about two hours,"—says Dr. Dowler—"the headless trunk exhibited such phenomena as are usually attributed to the brain,—namely, sensation, volition, and intelligential motion, as tested by the application of bits of ignited paper, wounds, and the like, whereupon the usual indicants of pain were elicited with great promptness and precision: it trembled, receded, rolled over, curved, placed its limbs accurately to the exact spot, and removed the offending cause. In certain places, this was exceedingly difficult, as on the spine between or near the shoulders or hips. It always used the limb the best adapted for the purpose. If the fire was too remote, as when applied to the tail, the whole body was thrown into the most favourable position for the purpose of reaching and removing the same. If the fire was placed on the table, in a position to annoy, yet without touching, the animal, as if endowed with sight, reached, and always accurately, to the exact spot, and either extinguished the fire, or removed it. As upon former occasions, if the animal found that the fire was continued at the same spot, and that it could not remove it, which was sometimes the case, owing to continuous or repeated applications, and carefully manœuvring, it curved the body,—scratched violently, manœuvred skilfully, and then, as a last resort, rolled quite over, laterally, always *from*, never *towards* the fire and operator."

Still, the position, that in man and the upper classes of animals,

the brain is the organ through which the mind acts in the production of the different mental and moral manifestations, can scarcely be contested.[1] Yet, amongst those who admit the accuracy of this conclusion, a difference of sentiment exists,—some conceiving that other organs participate in the function. To each of the known temperaments as many intellectual and moral dispositions have been ascribed. It has been affirmed, that if the brain be manifestly the organ of intellect the passions must be referred to the organs of internal or organic life; whilst others have regarded the brain as a great central apparatus for the reception and elaboration of the different impressions made upon the external senses;—thus conceiving the latter to be direct agents in the execution of the function, as well as the brain.

The influence of the temperaments upon the mental and bodily powers is much less invoked at the present day than it was of old. The ancients esteemed organized bodies to be an assemblage of elements, endowed with different qualities, but associated and combined so as to moderate and *temper* each other. Modern physiologists mean by temperament, the reaction of the different organs of the body upon each other consistently with health; so that if one set or apparatus of organs predominates, the effect of such predominance may, it is conceived, be exerted on the whole economy. In the description of the temperaments in different authors we find a particular character of intellectual and moral faculties assigned to each. The man of *sanguine* temperament is described as of ready conception, retentive memory, and lively imagination; inclined to pleasure, and generally of a good disposition; but inconstant and restless. He of the *bilious*, on the other hand, is said to be hasty, violent, ambitious, and self-willed; whilst the *lymphatic* temperament bestows feeble passions; cold imagination; tendency to idleness; and the *melancholic* disposes to dulness of conception, and to sadness and moroseness of disposition. M. Gall[2] has animadverted on this assignment of any intellectual or moral faculty to temperament. If we look abroad, he affirms, we find the exceptions more numerous than the rule itself; so numerous, indeed, as to preclude us from establishing any law on the subject. Moreover, the idiot, who possesses a temperament like other persons, has no intellectual faculties. The temperament, doubtless, influences the brain within certain limits, as it does other functions: this, he suggests, it probably does by impressing them with a character of energy or of languor, but without, in any respect, regulating the intellectual sphere of the individual.

Bichat,[3] again, maintained, that whilst the encephalon is evidently the seat of the intellectual functions, the organic nervous system, and, consequently, the different organs of nutrition, which are supplied by it, are the seat of emotions or passions. That distinguished physiologist, than whom, as M. Corvisart wrote to the First Consul, on announcing his death, "*personne en si peu de temps n'a fait tant de*

[1] Gall, Sur les Fonctions du Cerveau, ii. 69, Paris, 1825; Adelon, art. Encéphale, Dict. de Médec., vii. 517; and Physiologie de l'Homme, ed. cit., i. 496.

[2] Op. citat., ii. 140.

[3] Sur la Vie et la Mort, Part i., Paris, 1806.

choses et aussi bien,"[1] rests his views upon the following considerations:—1st. That while inward feeling induces us to refer intellectual acts to the brain, the passions are referred to the viscera of the thorax or abdomen. 2dly. That the effects of intellectual labour are referred to the encephalon, as indicated by redness and heat of face, and beating of the temporal arteries in violent mental contentions, &c.: whilst the passions affect the organic functions, the heart is oppressed, and its pulsations are retarded or suspended; the respiration becomes hurried and interrupted; the digestion impeded or deranged, &c.; and 3dly. That whilst our gestures and language refer intellect to the encephalon, they refer emotions to the nutritive organs. If we wish to express any action of the mind, or are desirous of recalling something that has escaped the memory, the hand is carried to the head; and we are in the habit of designating a strong or weak intellect as a "strong or weak *head;*" or we say, that the possessor has "much or little brain." On the other hand, if desirous of depicting the passions, the hand is carried to the region of the stomach or heart; and the possessor of benevolent or uncharitable sentiments is said to have a good or a bad *heart.* Bichat properly adds, that this idea is not novel, inasmuch as the ancients conceived the seat of the passions to be in the epigastric centre;—that is, in the nervous plexuses situate in that region. He remarks that amidst the varieties presented by the passions, according to age, sex, temperament, idiosyncrasy, regimen, climate, and disease, there is always a ratio between them and the degree of predominance of the different nutritive apparatuses; and he concludes with a deduction, which ought not to have been hazarded without full reflection,—that as the functions of the nutritive organs, in which he ranges the passions, are involuntary, and consequently uninfluenced by education, education can have no influence over the passions, and the *disposition* is consequently incapable of modification.

The answer of MM. Gall[2] and Adelon[3] to the views of Bichat appears to us to be irrefragable. How can we conceive, that viscera, whose functions are known, and which differ so much from each other, are agents of moral acts? The passions are sensorial phenomena, and like all phenomena of the kind, must be presumed to be seated in essentially nervous organs. Again;—when an injury befalls the brain, and the intellectual faculties are perverted or suspended by it, the same thing happens to the affective faculties; and if the viscera fulfil the high office assigned to them, why are not the passions manifested from early infancy, a period when the viscera are in existence and active? The argument of Bichat—that the phenomena which attend and follow the passions, are referable to the nutritive organs—is not absolute. The functions of animal life are frequently disturbed by the passions, as well as those of organic life. It is not uncommon for them to induce convulsions, mania, epilepsy, and other affections of the encephalon. The effect here, as M. Adelon remarks, is mistaken for the cause. The

[1] Eloge de Xavier Bichat, par Miquel, p. 58, Paris, 1823.
[2] Op. citat., i. 94.
[3] Art. Encéph. (Physiol.) in Dict. de Méd., vii. 521, and Physiologie de l'Homme, edit. cit., i. 510.

heart certainly beats more forcibly in anger, but the legs fail us in fear; and if we refer anger to the heart, we must, by parity of reasoning, refer fear to the legs. By reasoning of this kind, the passions might be referred to the whole system, as there is no part which does not suffer more or less during their violence. The error arises from our being impressed with the most prominent effect of the passion—the feeling accompanying it—and this is the cause of the gesture and the descriptive language, to which Bichat has given unnecessary weight in his argument. If, then, the views of Bichat, regarding the seat of the passions, be unfounded, the mischievous doctrine deduced from them—that they are irresistible, and cannot be modified by education—falls to the ground. His notion was, that the nutritive organs are the source of irritative irradiations, which compel the brain to form the determinations that constitute the passion, and to command the movements by which it is appeased or satisfied. A similar view is embraced by M. Broussais,[1] who, however, conceives, that the passions can be fomented and increased by attention, until they become predominant. Daily experience, indeed, exhibits the powerful effect produced on the passions by well-directed moral restraint. How many gratifying instances have we of persons, whose habitual indulgence of the lowest passions and propensities had rendered them outcasts from society, having become restored to their proper place by exerting due control over their vicious inclinations and habits! We can not only curb the expression of the passions, as we are constantly compelled to do, in social intercourse; but even modify the internal susceptibility by well-directed habits of repression.

Lastly. Many physiologists have considered the brain as a great nervous centre for the reception and elaboration of different impressions conveyed thither by the external senses; and absolutely requiring such impressions for the mental manifestations. They consequently rank, amongst the conditions necessary for such manifestations, not only the brain which elaborates them, but the parts that convey to it the impressions or materials on which it has to act; and conceive, that a necessary connexion exists between these two orders of parts. The supporters of these opinions ascribe the differences observed in the intellectual and moral faculties of different persons as much to diversity in the number and character of the impressions, as to differences in the encephalon itself. They do not all, however, agree as to the source of the impressions, which they conceive to be the *raw material* for the intellectual and moral acts. M. Condillac[2] and his school admit only one kind;—those proceeding from the external senses, which they term *external impressions*. M. Cabanis,[3] in addition to these, admits others proceeding from every organ in the body, which he terms *internal impressions*.

The school of Condillac set out with the maxim ascribed to Aristotle, "*nihil est in intellectu quod non prius fuerit in sensu;*" and they adopt, as an elucidation of their doctrine, the ingenious idea of Condillac—of a statue, devoid of all sensation, which is made to receive each of the

[1] Examen des Doctrines Médicales, ii. 388, and Physiology applied to Pathology, Drs. Bell and La Roche's translation, p. 136, Philadelphia, 1832.
[2] Traité des Sensations, i. 119.
[3] Rapport du Physique et du Moral de l'Homme, 4ème édit., par G. Pariset, Paris, 1824.

five senses in succession; and which, he attempts to show, from the impressions received, may be able to develope gradually the different intellectual and moral faculties. All these, he affirms, are derived from impressions made on the external senses; and he considers the whole of human consciousness to be sensation variously transformed.

The views of M. Condillac have been largely embraced, with more or less modification; and, at the present day, many metaphysicians believe, that impressions on the senses are the necessary and exclusive materials for all intellectual acts. His case of the statue seems, however, to be by no means conclusive. It must, of course, be possessed of a centre for the reception of impressions made upon different senses, otherwise no perception could occur; and if we can suppose it possible for such a monstrous formation as a being totally devoid of external senses to exist; such a being must not only be defective in the nerves which, in the perfect animal, are destined to convey impressions to the brain, but probably in the cerebral or percipient part likewise. From defective cerebral conformation, therefore, the different mental phenomena might not be elicited.[1] If, however, we admit in such a case the possibility of the cerebral structure,—particularly of those portions that are especially concerned in the function of thought,—being properly organized, it appears to us, that certain mental or moral manifestations ought to exist. Of course, all knowledge of the universe would be precluded, because deprived of the *instruments* for obtaining such knowledge; but the brain would act as regarded the internal sensations. In order that such a being may live, he must be supplied with the necessary nourishment; possess all those internal sensations or wants that are inseparably allied to organization; and must, consequently, feel the desires of hunger and thirst; but we have seen, that these sensations require the intervention of the brain as much as the external sensations. Supposing him, again, to survive the period of puberty, he must experience the instinctive changes, which occur at this period, and which must furnish impressions to the encephalon. In this assumed case, then, a certain degree of mental action might exist; and, under the supposition of a properly organized brain, ideas—limited, it is true, in consequence of the privation of the ordinary inlets of knowledge—might be formed; and memory, imagination, and judgment be compatible within certain limits.

The objections to the view, that the intellectual and moral sphere of man and animals is proportionate to the number and perfection of the external senses are overwhelming. Animals have the same number of senses as man, and, frequently, have them more perfect; yet in none is the mental sphere co-extensive. The idiot has the external senses as delicate as the man of genius, and often much more so; many of those of the greatest talents having the senses extremely obtuse. It has been already remarked, that the superiority of the human intellect has been referred entirely to the sense of touch, and to the happy organization of the human hand; but the case of Miss Biffin, and others, and that of the young artist cited by M. Magendie,[2] negative this pre-

[1] Adelon, op. citat., i. 519.

[2] See page 140 of this volume.

sumption. The senses are important secondary instruments,—indispensable for accomplishing certain manifestations of the mind, but, in no way, determining its power.

The example of the deaf and dumb is illustrative of this matter.[1] If a child be born deaf, he is necessarily dumb; inasmuch as he is unable to hear those sounds which, by their combination, constitute language; and cannot therefore imitate them;—a connexion between the functions of hearing and speech, which was not well known to the ancients. For a length of time, these objects of compassionate interest were esteemed to be beyond the powers of any kind of intellectual culture, and were permitted to remain in a state of the most profound ignorance. The ingenuity of the scientific philanthropist has, however, devised modes of instruction, by which their mental power has been exhibited in the most gratifying manner, and in a way to prove, that the sense of hearing is not indispensable for mental development; but that its place may be supplied, to a great extent, by the proper exercise of others. The deaf and dumb, deprived of the advantages of spoken language, are compelled to have recourse to the only kind available to them,—that addressed to the eye. In this typical way, by a well-devised system of instruction they can be taught to preserve their ideas, and to multiply them, like the perfectly formed, by the spoken and written language,—without one or the other of which the human mind would have remained in perpetual infancy. Thus, the deaf and dumb have not only like ideas; but the same words to convey them to others.

Yet the deaf and dumb are not so much the objects of our commiseration as they who have been deprived, from birth or from early infancy, of both sight and hearing, and have thus been devoid of two of the most important inlets for the entrance of impressions from the surrounding world. In such case, it is obvious, they are shut out from all instruction, except what can be afforded by the senses of touch, smell, and taste; yet even here we have the strongest evidence of independent intellect. One of the most striking cases of the kind is that of the Scotch boy Mitchell, the object of much interest to Spurzheim and to Dugald Stewart,[2] both of whom have described his case in their writings. It is matter of uncertainty, whether either his deafness or blindness was total. The evidences of the sensation of hearing were, in a high degree, vague and unsatisfactory; but he gave more convincing proofs of the possession of partial vision. He could, for example, distinguish day from night; and, when quite young, amused himself by looking at the sun through crevices in the door, and by kindling a fire. At the age of twelve, the tympanum of each ear was perforated; but without any advantage. In his fourteenth year, the operation for cataract was performed on the right eye, after which he recognized more readily the presence of external objects; but never made use of sight to become acquainted with the qualities of bodies. Before and after this period, red, white, and yellow particularly attracted his at-

[1] Gall, op. cit., i. 119.

[2] Elements of the Philosophy of the Human Mind, &c.; Transactions of the Royal Society of Edinburgh, vol. vii.; and Dr. Gordon, ibid., vol. vi.; also, History of James Mitchell, a boy born blind and deaf, by James Wardrop, London, 1813.

tention. The senses, by which he judged of external bodies, were those of touch and smell. His desire to become acquainted with objects was great. He examined every thing he met with, and each action indicated reflection. In his infancy, he smelt at every one who approached him; and their odour determined his affection or aversion. He always recognized his own clothes by their smell; and refused to wear those which he found to belong to others. Bodily exercises, such as rolling down a small hill, turning topsy-turvy, floating wood or other objects on the river that passed his father's house; gathering round, smooth stones, laying them in a circle, and placing himself in the middle, or building houses with pieces of turf, &c., were a source of amusement to him. After the operation on his right eye, he could better distinguish objects. His countenance was very expressive; and his natural language not that of an idiot, but of an intelligent being. When hungry, he carried his hand to his mouth, and pointed to the cupboard where the provisions were kept; and, when he wished to lie down, reclined his head on one side upon his hand, as if he wished to lay it upon the pillow. He easily recollected the signification of signs that had been taught him; all of which were of course of the tactile kind. To make him comprehend the number of days before an event would happen, they bent his head as a sign that he would have to go to bed so many times. Satisfaction was expressed by patting him on the shoulder or arm; and discontent by a sharp blow. He was sensible of the caresses of his parents; and susceptible of different emotions—hatred, passion, malice, and the kindlier feelings. He was fond of dress, and had great fears of death, of the nature of which he had manifestly correct notions. Mitchell's case has been pregnant with interest to the metaphysician; but it is not so elucidative as it would have been had the privation of the senses in question been total.

There is, or was, in the American Asylum at Hartford in Connecticut, a being not less deserving of attention than Mitchell.[1] Her name is Julia Brace. She is the daughter of John and Rachel Brace, natives of Hartford, and was born in that town in June, 1807; so that she is now (1850) forty-three years old. At four years of age she was seized with typhus fever; was taken sick on the evening of Monday, November 29, 1811; and, on the Saturday morning following, became both *blind* and *deaf*. Prior to her illness, she had not only learned to speak, but to repeat her letters, and to spell words of two or three syllables; and, for some time after the loss of her sight and hearing, she was fond of taking a book, and spelling words and the names of her acquaintances. She retained her speech pretty well for about a year; but gradually lost it, and appears to be now condemned to perpetual silence. For three years she could still utter a few words, one of the last of which was "*mother*." At first she was unconscious of her misfortune, appearing to think, that a long night had come upon the world; and often said, "It will never be day." She would call upon the family to "light the lamp," and was impatient at their seeming

[1] Twenty-first Report of the Directors of the American Asylum at Hartford, for the Education and Instruction of the Deaf and Dumb, p. 15, Hartford, 1837, et seq.

neglect, in not even answering her. At length, in passing a window, she felt the sun shining warmly upon her hand; and pointed with delight to indicate that she recognized this. From the January after her illness, until the following August, she would sleep during the day, and be awake through the night; and it was not until autumn, by taking great pains to keep her awake during the day, that she was set right. At present, she is as regular in this respect as other persons. From the period of her recovery, she seemed to perceive the return of Sabbath; and, on Sunday morning, would get her own clean clothes, and those of the other children. If her mother was reading, she would find a book, and endeavour to do so likewise. The intervention of a day of fasting or thanksgiving confused her reckoning; and some time elapsed before she got right. During the first winter after her recovery, she was irritable almost to madness; would exhibit the most violent passion, and use the most profane language. The next summer she became calmer; and her mother could govern her, to some extent, by shaking her, in sign of disapprobation; and stroking or patting her head, when she conducted herself well. She is now habitually mild, obedient and affectionate. During the first summer after her illness, she was very unwilling to wear clothes, and would pull them off violently. At length, her mother took one of her frocks and tried it on her sister, with a view of altering it for her. Julia had ever been remarked for her sense of justice in regard to property. This seemed to be awakened; and she took the frock and put it on herself. After this she was willing to wear clothes, and even cried for *new ones*. She has ever since been fond of dress. At nine years of age she was taught to sew; and, since that time, has learned to knit. She has been a resident for several years in the American Asylum at Hartford; where she is supported in part, by the voluntary contributions of visitors, and, in part, by her own labours in sewing and knitting. A language of palpable signs was early established as a means of communication with her friends; and this has been so improved as to be sufficient for all necessary purposes. Her countenance, as she sits at work, is said to exhibit the strongest evidence of an active mind, and a feeling heart: "thoughts and feelings," says a writer who describes her case, "seem to flit across it like the clouds in a summer sky: a shade of pensiveness will be followed by a cloud of anxiety or gloom; a peaceful look will perhaps succeed; and, not unfrequently, a smile lights up her countenance, which seems to make one forget her misfortunes. But no one has yet penetrated the darkness of her prison house, or been able to find an avenue for intellectual or moral light. Her mind seems, thus far, inaccessible to all but her Maker."

A still more interesting example is cited by Dr. Abercrombie[1] from the Medical Journals of the time. A gentleman in France lost every sense except feeling on one side of his face; yet his family acquired a method of holding communication with him, by tracing characters upon the part which retained its sensation. These cases are not, perhaps, so unfrequent as has been supposed. Dr. Howe, the superintendent of

[1] Inquiries concerning the Intellectual Powers, &c., Amer. edit., p. 56, New York, 1832.

the Perkins Institution and Massachusetts Asylum for the Blind, stated, some years ago, that four cases in New England, besides that of Julia Brace, had come within his own observation. One of these had been in 1841 upwards of three years under his care; and the results of his diligence and judgment in this instance have furnished more gratifying results to the psychologist and philanthropist than any, perhaps, on record.

Laura Bridgman, the subject of the case, was born in December, 1829. At two years of age, her eyes and ears inflamed, suppurated, and their contents were discharged. At the expiration of two more years of suffering, it was discovered, that her sense of smell was almost wholly destroyed; and, consequently, that her taste was much blunted. She had, therefore, but one sense remaining, that of touch, by which she could become acquainted with the external world. Whilst at home, before her reception into the Asylum, she would explore the house; become familiar with the form, density, weight, and temperature of every article she could lay her hands upon; followed her mother; felt her hands and arms, and endeavoured to repeat every thing herself. She even learned to sew a little, and to knit. She exhibited warm affection towards the members of her family; but the means of communicating with her were limited. When it was desired that she should go to a place, she was pushed; or that she should approach, she was drawn towards the person. Gently patting on the head signified approbation; on the back, disapprobation. She had made, however, a natural language of her own; and had a sign to express her idea of each member of the family,—such as drawing her finger down each side of her face, to allude to the whiskers of one; twirling her hand and arm around, in imitation of the spinning-wheel, for another, &c.

In October, 1837, she was received into the Institution for the Blind, in Boston. The first experiments made with her consisted in taking articles in common use; such as knives, forks, spoons, keys, &c., and pasting labels upon them with their names printed in raised letters. These she felt very carefully; and speedily found, that the crooked lines *spoon* differed as much from the crooked lines *key*, as the spoon differed from the key in form. Small detached labels, with the same words printed upon them, were then put into her hands, and she soon observed, that they were similar to the ones pasted on the articles. She showed her perception of this similarity by laying the label *key* upon the key, and the label *spoon* upon the spoon. In this manner she proceeded to acquire a knowledge of language; used the manual alphabet of the deaf mutes with great facility and rapidity, and increased her vocabulary so as to comprehend the names of all common objects. She could soon count to high numbers; and add and substract small ones. But the most gratifying acquirement which she made, and the one which gave her the most delight, was the power of *writing a legible hand*, and expressing her thoughts upon paper. She writes with a pencil in a grooved line, and makes her letters clear and distinct. The author has a favourable specimen now before him, in a recent well conceived, and well expressed, letter to a friend. She is expert with her needle; knits easily, and can make twine bags and various fancy articles very

prettily; is docile; has a quick sense of propriety; dresses herself with great neatness, and is always correct in her deportment. No definite course of instruction could be marked out; for her inquisitiveness was so great, that she was very much disconcerted if any question, which occurred to her, was deferred until the lesson was over. It was deemed best to gratify her, if her inquiry had any bearing on the lesson; and often she led her teacher far away from the objects with which he commenced. With regard to the sense of touch it is very acute, even for a blind person. It is shown remarkably in the readiness with which she distinguishes persons. There were, a few years ago, forty inmates in the female wing, with all of whom she was acquainted. Whenever she is walking through the passage-way, she perceives by the jar of the floor, or the agitation of the air, that some one is near her, and it is exceedingly difficult to pass her without being recognized. Her arms are stretched out, and the instant she grasps a hand, a sleeve, or even part of the dress, she knows the person, and lets him pass on with some sign of recognition.

The details concerning this interesting being, and her gradual progress in moral and intellectual culture, can be learned from the annual reports of the Institution, which Dr. Howe so ably superintends.[1]

How strongly do these cases demonstrate the independence of the organ of intellect; requiring, indeed, the external senses for its perfect developement, but still capable of manifesting itself without the presence of many, and probably of any, of them; and how inaptly, although humanely, does the law regard such beings! "A person," says Blackstone,[2] "born *deaf*, *dumb*, and *blind*, is looked upon by the law as in the same state with an idiot, he being supposed incapable of any understanding, as wanting all those senses which furnish the human mind with ideas." But if he *grow* deaf, dumb, and blind, not being *born* so, he is deemed *non compos mentis*, and the same rules apply to him as to other persons supposed to be lunatics. With regard to the deaf and dumb, they are properly held to be competent as witnesses, provided they evince sufficient understanding, and to be liable to punishment for a breach of the criminal laws.

M. Cabanis[3] embraces the views of Condillac regarding the external senses; but thinks, that impressions from these are insufficient to constitute the *matériel* of the mental and moral manifestations. In confirmation of this opinion, he observes, that the young infant, and animals at the very moment of birth, frequently afford evidences of complicated acts originating in the nervous centres; and yet the external senses can have been but little impressed. How can we, he asks, refer to the operation of the external senses the motions of the fœtus in utero, which are perceptible to the mother, for the latter half of utero-gestation; or the act of sucking executed from the first day of existence? Can we refer to this cause the fact of the chick, as soon as it is hatched, pecking the grain that has to nourish it? or the one, so frequently

[1] Annual Reports of the Trustees of the Perkins Institution and Massachusetts Asylum for the Blind to the Corporation, for the years 1837, et seq.

[2] Commentaries on the Laws of England, i. 304.

[3] Rapport du Physique et du Moral, edit. cit.

quoted from Galen, of the young kid, scarcely extruded from the maternal womb, and yet able to select a branch of the cytisus from other vegetables presented to it? Man and animals, continues M. Cabanis, during the course of their existence, experience mental changes as remarkable as they are frequent; yet nothing in the condition of the senses can account for such difference. For example, at the period of puberty, a new appetite is added; and this, even, when the being is kept in a complete state of isolation. This, he argues, it is impossible to refer to any change in the external senses; which, if they furnished the materials at all, must have been doing so from early infancy; and he concludes, that the difference observable in the mental manifestations, according to sex, temperament, climate, state of health or disease, regimen, &c., cannot be referable to the senses, as they remain the same; and, consequently, we must look elsewhere for the causes of such difference. These M. Cabanis conceives to be the movements by which the organs of internal life execute their functions. Such movements, he says, although deep-seated and imperceptible, are transmitted to the brain, and furnish that organ with a fresh set of materials. At puberty, when the testicles become developed, and their function is established by the secretion of sperm, the organic movements during the secretion are the materials of the new desires, which appear at that age. These impressions he calls *internal*, in contradistinction to the *external*, or those furnished by the five senses; and he considers, that whilst the external senses serve as the basis for all that we include under the term *intellect*, the internal impressions are the materials of what are called *instincts;* and, as the organs of internal life, whence the internal impressions proceed, vary more than the senses, according to age, sex, temperament, climate, regimen, &c., it is more easy to find in them organic modifications, which coincide with those exhibited by the mind under those various circumstances.

In proof of these opinions, he adduces, besides others, the following specious affirmations. *First.* As the venereal appetite appears in man and animals synchronously with the developement of the testicles, and is never exhibited when they are removed in infancy, we have reason to believe, that the impressions, which constitute the materials for this new catenation of ideas, must proceed from the testicles. *Secondly.* Numerous facts demonstrate, that the condition of the uterus has much influence on the mental and moral manifestations of the female. The period of the developement of that organ, for example, is the one at which new feelings arise, and all those manifestations assume more activity; and there is generally a ratio between their activity and that of the uterus. If the state of the uterus be modified, as it is at the menstrual period, or during pregnancy, or after delivery, the mind is so likewise. All these facts ought to induce a belief, he thinks, that impressions are continually emanating from that organ, which, by their variety, occasion the diversity in the state of mental and moral faculties observed in those different cases. *Thirdly.* It is impossible in the *hypochondriac* and *melancholic* constitutions, to mistake the influence exerted upon the mind by the abdominal organs. According as they execute their functions more or less perfectly, the thinking faculty is

more or less languid or brilliant; and the affections more or less vivid and benevolent, or the contrary; hence the expressions *melancholy*[1] and *hypochondriasis*,[2] assigned to the states of mind characterizing those constitutions, which denote that the cause must be referred to the abdominal organs. The origin of the alternations of inactivity and energy in the intellect, of benevolent and irascible fits of humour, as well as of insanity, is also referable, he says, to the abdominal viscera. Hence—M. Cabanis concludes—it is evident, that the abdominal organs are the source of fortuitous and abnormous impressions which excite the brain to irregular acts;—and is it not, he asks, probable, that what takes place in excess, in these morbid movements, may happen to a less and more appropriate extent in health; and that thus impressions may emanate in a continuous manner from every organ of the body, which may be indispensable to the production of the mental and moral acts? M. Cabanis, therefore, considers that the axiom of Aristotle should be extended; and that the statue of Condillac is incomplete, in not having internal organs for the emanation of internal impressions, which are the materials of the instincts. In this way he accounts for the instincts, which, by some metaphysicians, have been looked upon as judgments, executed in the ordinary manner. but so rapidly, that the process has ceased from habit to be perceptible. *Finally*, he remarks, there is a ratio between the duration and intensity of the intellectual results and the kind of impressions, which have constituted their materials. All the mental and moral acts, for instance, that are derived from impressions engendered in the very centre of the nervous system or in the brain,—such as those of the maniac,—are the strongest and most durable. After these come the *instincts*, of which the internal impressions are the materials: they are powerful and constant;—and lastly, the intellectual acts, which are more transient, because they emanate from external impressions, themselves fickle, and somewhat superficial.

According to the views, then, of M. Cabanis and his followers, amongst the organic conditions of the mental and moral manifestations must be placed, not only those of the encephalon and external senses, but of the different organs of the body, which furnish the various internal impressions. The influence of the external senses on the intellectual and moral developement has already been canvassed: we have seen, that they are only secondary instruments for making us acquainted with external bodies, and that they in nowise regulate the intellectual and moral sphere. The notion of internal impressions is ingenious, and has led to important improvements in the mode of investigating the different mental and moral phenomena. It was suggested, as has been shown, by M. Cabanis, in consequence of the external senses appearing to him insufficient to explain all the phenomena. By MM. Gall, Adelon,[3] and others, however, all these cases are considered explicable by the varying condition of the brain itself. In the fœtus in utero; in the new-born animal, there are already parts of the brain, they say, sufficiently developed; and, accordingly, we witness the actions to which reference

[1] From μελας, "black," and χολη, "bile."
[2] Disease of the hypochondres.
[3] Physiologie de l'Homme, 2de édit., i. 251.

has been made by M. Cabanis; and if the intellectual and moral manifestations vary according to sex, temperament, climate, regimen, state of health, &c., it is because the encephalon is, under these circumstances, in different conditions. The chief facts, on which M. Cabanis rests his doctrine, are,—the coincidence between the developement of the testicles and the appearance of the venereal appetite; and the suppression of this appetite after castration. It must be recollected, however, that these are not the only changes, that happen simultaneously at puberty. The voice assumes a very different character; but the change in the voice is not a cerebral phenomenon. It is dependent upon the developement of its organ, the larynx. Yet castration, prior to puberty, has a decided effect upon it; preventing it from becoming raucous and unmelodious. All these developements are synchronous; but not directly consequent upon each other. The generative function has two organs,—one *central*, the other *external;* and it is not surprising, that both should undergo their developement at the same period.

On the whole, we are perhaps justified in concluding, that the brain alone is the organ of the intellectual and moral faculties. Yet, as before remarked, there is great force in the facts and arguments brought forward by Dr. Carpenter in favour of the emotional acts being seated in what, he terms, the sensorial ganglia: and that as we descend in the animal scale, the cerebrum or organ of the mental manifestations becomes less and less developed, until we ultimately find an encephalic organization in which a common sensorium for the reception of sensation and the origination of motion may alone exist; without any organ for the recording of impressions like the cerebrum in more highly endowed organisms. In such case, the motions may be mere responses to sensations experienced, without the presence of the slightest consciousness on the part of the being, or knowledge of the adaptation of means to ends. Still, it may be a question whether such sensations and responsive motions are not possessed by animals devoid of anything resembling the encephalic sensory ganglia of higher organisms, and which are wholly supplied with nerves of the excito-motory class—as the stomato-gastric. The interesting topic of the various instinctive operations of the frame will be considered in another part of this work. We shall there find, that instinct cannot in all cases be defined, in the language of M. Broussais,[1] to consist in sensations originating in the internal and external sensitive surfaces, which solicit the cerebral centre to acts necessary for the exercise of the functions,—such acts being frequently executed without the participation of mind, and even in its absence,—inasmuch as it is not confined to beings possessed of brain, but exists also in the vegetable.

Having now decided upon the organ of the mental and moral faculties, it would be necessary, according to the system adopted in this work, to describe its anatomy; but this has been done elsewhere.

[1] Physiol. appliquée à la Pathologie, ch. vii.; or Drs. Bell and La Roche's translation, Philad., 1832.

PHYSIOLOGY OF THE INTELLECTUAL AND MORAL FACULTIES.

When the organ of the intellect is exposed by accident, and we regard it during the reception of a sensation, the exercise of volition, or during any intellectual or moral operation, the action is found to be too molecular to admit of detection. At times, during violent mental contention, a redness of the surface of the brain has been apparent, as if the blood had been forced more violently into the vessels; but no light has been thrown by such examination on the wonderful actions that constitute thought. We ought not, however, to be surprised at this, when we reflect, that the most careful examination of a nerve does not convey to us the slightest notion how an impression is received by it from an external body; and how such impression is conveyed to the brain. All that we witness in these cases is the result; and we are, therefore, compelled to study the intellectual and moral acts by themselves, without considering the cerebral movements concerned in their production. Such study is the basis of a particular science—*metaphysics*, *ideology*, or *philosophy*. Apart from organization, this subject does not belong to physiology; but as some of the points of classification, &c., are concerned in questions that will properly fall under consideration, it may be well to give a short sketch of the chief objects of metaphysical inquiry; which are, indeed, intimately connected in many of their bearings,—as commonly treated by the metaphysician,—with physiology. M. Broussais has considered, that metaphysics and physiology should be kept distinct; and that all the investigations of the metaphysician should be confined to the ideal. "I wish metaphysicians, since they so style themselves," he remarks, somewhat splenetically, "would never treat of physiology; that they would only occupy themselves with ideas as ideas, and not as modifications of our organs; that they would never speak either of the brain, the nerves, the temperaments, or of the influence of climates, of localities, or of regimen; that they would never inquire whether there are innate ideas, or whether they come through the medium of the senses; that they would not undertake to follow their developements according to age or state of health; for I am convinced that they cannot reason justly on these points. Such questions belong to physiologists, who can unite a knowledge of the moral nature with that of the structure of the human body." "It is possible," he adds, "that particular circumstances may oblige them to introduce physiological considerations into their calculations; as when it is necessary to estimate the influence of certain laws or customs in relation to temperature, to the nature of the soil, the prevailing diseases, &c., but then they should avail themselves of the experience of physiologists and physicians."[1] A more appropriate recommendation would be that the metaphysician should make a point of becoming acquainted with physiological facts and reasoning; and, conversely, that metaphysics should form a part of the study of every physiologist.

The cerebral manifestations comprise two very different kinds of acts;—the *intellectual* and the *moral;* the former being the source of

[1] De l'Irritation et de la Folie, Paris, 1828; or Dr. Cooper's translation, Columbia, S. C., 1831.

all the knowledge we possess regarding ourselves and the bodies surrounding us; the latter comprising our internal feelings, appetites, desires, and affections, by which we are incited to establish a relation with the beings around us:—the two sets of acts respectively embracing the *qualities of the mind*, and those *of the heart*.[1]

If we attend to the different modes in which the intellectual manifestations are evinced in our own persons, we find, that there are several acts which are by no means identical. We are conscious of the difference between appreciating an impression made upon one of the external senses, which constitutes *perception*, and the recalling of such impression to the mind, which is the act of *memory;* as well as the distinction between feeling the relations, that connect one thing with another, constituting *judgment;* and the tendency to act in any direction, which we call *will*. The consciousness of these various mental processes has induced philosophers to admit the plurality of the intellectual acts, and to endeavour to reduce them all to certain *primary* faculties; in other words, to faculties which are fundamental or elementary, and by their combination give rise to other and more complex manifestations. To this analytical method they have been led by the fact, that the different acts, which they esteem elementary, exhibit great variety in their degrees of activity: one, for example, may be impressed with a character of energy—as the memory;—whilst another, as the judgment, may be singularly feeble;—and conversely. M. Broussais conceives, that without the memory we cannot exercise a single act of judgment; as it is always necessary, in order to judge, that we should experience two successive perceptions; which we could not do, unless possessed of the faculty of renewing that which we had felt before; in other words, unless we possessed memory. Hence the loss of this faculty, he says, necessarily occasions that of judgment, and reduces man to a state of imbecility. To a certain extent this is true. Total privation of memory must be attended with the results described. If an individual retains no consciousness of that which impressed him previously, there can obviously be no comparison. A man may, however, have an unusual memory for certain things and not for others; he may astonish us by the extreme accuracy of his recollection of numbers, places, or persons; and yet he may be singularly deficient in judging of other matters;—his memory suggesting only one train of objects for comparison.

In enumerating the faculties, which, by their union, constitute the intellect, we observe great discrepancy amongst metaphysicians. Some admit *will*, *imagination*, *understanding*, and *sensibility;* others, *sensibility*, *imagination*, *memory*, and *reason;* others *will*, *intelligence*, and *memory;* and others, again, *imagination*, *reflection*, and *memory*. The views of M. Condillac[2] on this subject have perhaps excited more attention than those of any other individual. Professing, as we have seen, that all our ideas are derived from successive operations of the senses and the mind, he admits the following constituent faculties of the intellect:—*sensation*, *attention*, *comparison*, *judgment*, *reflection*, *imagin-*

[1] Adelon, Facultés de l'Esprit et de l'Ame, in Dict. de Méd., viii. 469, Paris, 1823; and Physiologie de l'Homme, edit. cit., i. 527.
[2] Op. citat.

ation, and *reason*. *Sensation* he defines to be—the faculty of the mind, which affords the perception of any sensitive impression. *Attention*, the faculty of sensation, applied exclusively to a determinate object; being, as the word imports, the tension of the mind upon a particular object. *Comparison*, the faculty of sensation, applied to two objects at once. *Judgment*, the faculty by which the mind perceives the connexions, that exist between the objects compared. *Reason*, the faculty of running through a succession of judgments, which are connected with, and deduced from, each other. *Reflection*, as the word indicates, the faculty by which the mind returns upon itself, upon its own products, to prove their correctness, and to subject them again to its power; and *imagination*, to which Condillac attaches *memory*,—the faculty possessed by the mind of reproducing at will the different impressions, and all the products of its own operations. With regard to the order of catenation of these different faculties, he considers *sensation* to be first put in play; and if, amongst the perceptions, there is one, of which we have a more lively consciousness, and which attracts the mind to it alone, it is the product of *attention:* then comes *comparison*, which is nothing more than double attention: comparison is irresistibly succeeded by *judgment:* if, from one judgment, we pass to another deduced from it, we *reason;* if the mind turns back on its own production, we *reflect:* and lastly, if the mind spontaneously awakens its different perceptions *imagination* is in action. All these faculties are thus made to be deduced from each other; to originate in the first or sensation; and all are sensation successively transformed.

The doctrine of M. Condillac, abstractly considered, has already engaged attention. The division of the faculties, which he conceives, by their aggregation, to form the intellect, is simple and ingenious, and appears to be more easily referable to physiological principles than that of other metaphysicians; accordingly, it has been embraced, with more or less modification, by certain physiological writers.

The power of reflection, according to M. Broussais, is the characteristic of the human intellect; and to reflect is to feel. Man not only feels the stimulation produced by external agents, and by the movements of his own organs, which constitutes *sensation* or *perception*, but he is conscious that he has felt these stimulations: in other words, he *feels that he has felt;* he has, consequently, a perception of his actual perception, which, M. Broussais says, constitutes mental *reflection*. This process he can repeat as often as he thinks fit, and can observe all his sensations, and the different modes in which he felt, whilst occupied with his feelings. From this study he derives an idea of his own existence. "He distinguishes himself," to quote the dry description of M. Broussais, "in the midst of creation, and paying regard only to his own existence, compared with all that is not himself, he pronounces the word *I*, (*moi*,) and says, *I am;* and viewing himself in action, says, *I act*, *I do*, &c. Perception of himself and of other bodies procures him what are denominated *ideas*. This is, therefore, another result of reflection; in other words, of the faculty he possesses of feeling himself feel. But man feels, besides, that he has already felt: this constitutes *memory*. In comparing two perceptions with each other, which are felt in suc-

cession, a third perception results, which is *judgment*. Consequently, to judge is only to feel." "Hence," he concludes, "*sensation*, *reflection*, and *judgment* are absolutely synonymous, and present to the physiologist nothing more than the same phenomenon. The *will*, or the faculty by virtue of which man manifests his liberty by choosing, among different perceptions, the one he must obey;—the faculty, which gives him the power of resisting, to a certain extent, the suggestions of instinct—is founded on reflection. Consequently, when we consider it in a physiological point of view, we can only discover in it the faculty of feeling ourselves, and of perceiving that we feel ourselves."

Some of the later French metaphysicians have proposed certain modifications of the system of Condillac. M. De La Romiguière,[1] for instance, denies that sensation is the original faculty, and derives all from attention. The mind, he remarks, is passive during the reception of sensation, and does not commence action until directed to some object, or until it *attends*. According to him, the intellect consists of three faculties—*attention; comparison* or double attention; and *reason* or double comparison. Judgment, imagination, and memory are not primary faculties: judgment is the irresistible product of comparison; memory is but the trace, which every perception necessarily leaves behind it; and imagination is but a dependence on reason. M. Destutt-Tracy,[2] again, reduces the number of primary faculties to four—*perception*, *memory*, *judgment*, and *will* or *desire*. According to him, *attention* is not an elementary faculty. It is but the active exercise of the intellectual faculties. The same applies to *reflection* and *reason*, which are only a judiciously combined employment of those faculties; and to *comparison* and *imagination*, both of which enter into the judgment. This division is embraced by M. Magendie.[3] Mr. Dugald Stewart's[4] classification is into, 1, *Intellectual powers*, and, 2, *Active* and *moral powers;* including, in the former, *perception*, *attention*, *conception*, *abstraction*, the *associating principle*, *memory*, *imagination*, and *reason*. Dr. Brown[5] reduces all the *intellectual states* to *simple suggestion* and *relative suggestion*,—comprising in the former, *conception*, *memory*, and *imagination*,—in the latter, *judgment*, *reason*, *abstraction*, and *taste*. Dr. Abercrombie[6] considers the mental operations to be chiefly referable to *four heads*,—*memory*, *abstraction*, *imagination*, and *reason* or *judgment;* whilst Kant has twenty-five primary faculties or forms; pure conceptions or ideas *à priori*.

These are a few only of the discrepant divisions of psychologists. The list might have been extended by the classifications of Aristotle, Bacon, Hobbes, Locke, Bonnet, Hume, Vauvenargues, Diderot, Reid, and others. Perhaps the most prevalent opinion at present is, that the original faculties are—*perception*, *memory*, *judgment*, and *imagination*. It is impossible, were it even our province, to reconcile these discre-

[1] Leçons de Philosophie, tom. i. 4ème leçon.

[2] Elemens d'Idéologie, 2de édit., Paris, 1804.

[3] Précis Elémentaire, i. 196.

[4] Elements of the Philosophy of the Human Mind, 3d edit., Lond., 1808; and Amer. edit., Brattleborough, Vt., 1813.

[5] Lectures on the Philosophy of the Human Mind, Amer. edit., Boston, 1826.

[6] Inquiries concerning the Intellectual Powers, Amer. edit., p. 91, New York, 1832.

pancies. They are too considerable to hope, that this will ever be effected by metaphysical inquiry. We must, therefore, look to physiological investigation, if not with well-founded—with the only—hopes, we can entertain, for the elucidation of the subject; and we shall find presently, that the minds of metaphysical physiologists have been turned in this direction, and that many interesting facts and speculations have been the result.

A second topic of metaphysical inquiry regards the formation of the intellectual notions. On this, there have been two principal opinions; some, as Plato, Des Cartes, the Kantists, Kanto-Platonists, &c., believing in the existence of *innate ideas;*—others, as Bacon, Locke, and Condillac, denying the existence of such innate ideas, and asserting that the human intellect, at birth, is a *tabula rasa;* and that the mind has to acquire and form all the ideas it possesses from impressions made on the senses. The truth includes probably both these propositions,—the action of the senses and intellectual faculties being alike necessary;—the former receiving the external and internal impressions, and transmitting them to the mind, which, through the cerebral organ, produces the latter.

Under the terms *affective faculties*, *affections*, and *passions*, are comprehended all those active and moral powers, which connect us with the beings that surround us, and are the incentives to our social and moral conduct. To this class belong,—the feeling, which attaches the parent to the child; that which attracts the sexes; and compassion, by which we are led to assist a suffering fellow-creature. They are, in truth, internal sensations, but of a higher cast than those of hunger and thirst;—the latter being purely physical, and announcing physical necessities; the former suggesting social and moral relations. Such affective faculties are the foundation of what are called moral wants; and, like the internal sensations in general, are the source of *pleasure*, when satisfied,—of *pain*, when resisted; and it is only when they are extreme and opposed, that they acquire the name of *passions*.[1] The analysis of these is attended with the same difficulties as that of the intellectual faculties. Their plurality is universally admitted, but still greater discrepancy exists as to their precise number and connexion.[2] Many moralists have united the moral faculties under the head of *will* or *desires.* Condillac[3] is one of those. Every sensation, he observes, has the character of pleasure or pain, none being indifferent; as soon, therefore, as a sensation is experienced, the mind is excited to act. This tendency is at first but slightly marked, and is only an uneasiness (*malaise*); but it soon increases and becomes *restlessness* or *inquietude;*—in other words, a difficulty experienced by the mind of remaining in the same situation. This gradually becomes *desire*, *torment*, *passion*, and finally *will* excited to the execution of some act. Some have endeavoured, by ultimate analysis, to derive all the affective faculties from one principal faculty—that of *self-love*,—the inward feeling, which induces all to attend to themselves, their own preservation, and

[1] From *patior*, I suffer.

[2] Adelon, art. Affection, Dictionnaire de Médecine, 1ère édit.; and Physiologie de l'Homme, edit. cit., i. 537.

[3] Op. citat.

welfare. All the faculties, they assert, are returns of this self-love upon itself; and, as in the case of the intellectual faculties, attempts have been made to classify them; but scarcely two metaphysicians agree. Some have divided them into the *agreeable* and *distressing;* others into those of *love* and *hatred;* many—regarding their effects upon society—into the *virtuous*, *vicious*, and *mixed;*—the first comprising those that are useful to society,—as *filial*, *parental*, and *conjugal love*, which form the foundation of families; *goodness*, *pity*, and *generosity*, which, by inducing men to assist each other, facilitate the social condition; and the *love of labour*, *honour*, and *justice*, which have the same result, by constituting so many social guarantees. The vicious passions, on the contrary, are such as injure man individually, and society in general, as *pride*, *anger*, *hatred*, and *malice*. Lastly, the mixed passions are such as are useful or injurious, according to their use or abuse; as *ambition*, which may be a laudable emulation, or an insatiable passion, according to its extent and direction.

Again, the passions have been divided into the *animal* or such as belong to physical man, and the *social* or such as appertain to man in society. The first are guides for his preservation as well as for that of the species. To them belong *fear*, *anger*, *sadness*, *hatred*, *excessive hunger*, the *venereal desires* when vehement, *jealousy*, &c. In the second are included all the social wants when inordinately experienced. These vary according to the state of civilization of the individual and the community. *Ambition*, for instance, it is said, may be regarded, when inordinate, as excessive love of power:—*avarice*, as an exaggeration of the desire for fortune:—*hatred*, and *vengeance*, as the natural and impetuous desire of injuring those that injure us, &c. Mr. Dugald Stewart's[1] division of the *active* and *moral powers* embraces, 1. *Instinctive principles*, and 2. *Rational principles*,—the former including *appetites*, *desires*, and *affections;* the latter *self-love* and the *moral faculty;* all of which Dr. Brown[2] comprises under *emotions*, immediate, retrospective, or prospective;—and *lastly*, Dr. Abercrombie[3] refers all the principles, which constitute the moral feelings, to the following heads: 1. The *desires*, the *affections*, and *self-love;* 2. The *will;* 3. The *moral principle*, and 4. The *moral relation of man towards the Deity*.

It is obvious, that the analysis of the moral faculties has been still less satisfactorily executed than that of the intellectual; and that little or no attempt has been made to distinguish those that are primary or fundamental, from those that are more complex; consequently, the remarks which were made regarding the only quarter we have to look to, for any improvement in our knowledge of the intellectual acts, apply *à fortiori* to the moral; although it must be admitted, that the difficulties attendant upon the investigation of the latter are so great as to appear to be almost insuperable.

As the brain, then, is admitted to be the organ of the intellectual and moral faculties, it is fair to presume that its structure may be

[1] Op. citat. [2] Op. citat.
[3] Philosophy of the Moral Feelings, Amer. edit., p. 35, New York, 1833.

found to vary according to the number and character of those; and if there be primary or fundamental faculties, each may be conceived to have a special organ concerned in its production, as each of the external senses has its organ. According to this view, the cerebral organization of animals ought to differ according to their psychology: where one is simple, the other should be so likewise. This seems, so far as we can observe, to be essentially the fact. "In the series of animals," says M. Adelon,[1] "we observe the brain more complicated as the mental sphere is more extensive; and in this double respect a scale of gradation may be formed from the lowest animals to man. If he has the most extensive moral sphere, if he alone has elevated notions of religion and morality, he also has the largest brain, and one composed of more parts; so that if the physiology of the brain were more advanced, we might be able, by comparing the brains of animals with his, to detect the material condition, which constitutes humanity. If the brain were not constructed *à priori* for a certain psychology, as the digestive apparatus is for a certain alimentation; and if the mental and moral faculties were not as much innate as the other faculties, there would be nothing absolute in legislation or morals. The brain and its faculties are, however, in each animal species, in a ratio with the *rôle*, which such species is called upon to play in the universe. If man is, in this respect, in the first rank; if he converts into the delicate affections of father, son, husband, and country, those brute instincts by which the animal is attached to its young, its female, or kennel; if, in short, he possesses faculties which animals do not,—religious and moral feelings, with all those that constitute humanity,—it is owing to his having a more elevated vocation; to his being not only king of the universe, but destined for a future existence, and specially intended to live in society. Hence it was necessary, that he should not only have an intellect sufficiently extensive to make all nature more or less subject to him, but also a psychology such, that he might establish social relations with his fellows. It was necessary, that he should have notions of the just and the unjust, and be able to elevate himself to the knowledge of God;—to those sublime feelings, which cause him so to regulate his conduct as to maintain with facility his mortal connexions, and deserve the future life to which he is called."

But if the intellectual sphere be regulated by the cerebral developement, can we not, it has been asked, estimate the connexion between them? And if there be different primary cerebral faculties, each of which must have an organ concerned in its production, can we not point out such organ in the brain? Several investigations of this character have been attempted, with more or less success: generally, however, they have added but little to our positive knowledge, and this, principally, from the intricacy of the subject. Until of late years, attention was chiefly paid to the mass and size of the encephalon; and it was, at one time, asserted that the larger it is, in any species or individual, the greater the intellect. Man, however, has not absolutely the largest encephalon, although he is unquestionably the most intelligent of beings. The weight of the encephalon of a child six years of

[1] Art. Encéphale, in Dict. de Méd., vii. 526; and Physiologie de l'Homme, edit. cit., i. 524.

age is given by Haller at two pounds three ounces and a half; whilst that of the adult is estimated by Sömmering at from two pounds three ounces, to three pounds three ounces and three-quarters;[1] by Tiedemann[2] at from three pounds three ounces, to four pounds eleven ounces troy,—the brain of the female weighing, on an average, from four to eight ounces less than that of the male. The average weight, after the meninges have been stripped off, is, in the healthy adult male, according to M. Lelut,[3] about 1346 grammes, or three pounds and a half avoirdupois; of which the cerebrum weighs 1170, the cerebellum 176 grammes. In the female, the weight of the encephalon was about $\frac{1}{15}$th less. From the tables of weights of the brain given by Dr. Sims, Clendinning,[4] Tiedemann, and Dr. John Reid,[5] it was found that in a series of 278 cases the maximum weight of the adult male brain was 65 ounces: the minimum weight 34 oz. In a series of 191 cases, the maximum weight of the brain of the adult female was 56 oz.:—the minimum weight 31 oz. By taking the mean of all the cases, an average weight was deduced of 49½ oz. for the male; and of 44 oz. for the female brain; and although many female brains exceed in weight particular male brains, it is found that the adult male encephalon is heavier than that of the female, by from five to six ounces on an average.[6] The encephalon of the elephant, according to Haller, weighs from seven to ten pounds. The brain of an African elephant, seventeen years old, was found by Perrault to weigh nine pounds; that of an Asiatic elephant, weighed by A. Moulins, was ten pounds. Sir Astley Cooper dissected one that weighed eight pounds one ounce and two grains, avoirdupois.[7] These facts, consequently, overthrow the proposition; and, moreover, in certain insects, the bee and the ant, we meet with evidences of singular intelligence. The proposition was therefore modified, and it was laid down, that the larger the encephalon, compared with the rest of the body, the greater the mental sphere. When the subject was first investigated in this way, the result, in the case of the more common and domestic animals, was considered so satisfactory, that without farther comparison, the proposition was considered established. More modern researches have shown, that it admits of numerous exceptions; and that several of the mammalia, and many diminutive and insignificant animals have the advantage over man in this respect. It has, indeed, been properly observed by Mr. Lawrence,[8] that it cannot be a very satisfactory mode of proceeding, to compare the body, of which the weight varies so considerably, according to illness, emaciation, or *embonpoint*, with the brain, which is affected by none of those circum-

[1] Weber's Hildebrandt's Handbuch der Anatomie, Band iii. 423; Rudolphi, Grundriss, u. s. w. ii. 11, Berlin, 1823.

[2] Proceedings of the Royal Society for 1836; also Das Hirn des Negers mit des Europäers und Orang-outangs vergleichen, Heidelb., 1837, cited in Brit. and For. Med. Rev., for Oct. 1839, p. 374.

[3] Gazette Médicale; and Medico-Chirurgical Review for Oct., 1837, p. 507.

[4] Medico-Chirurgical Transactions, xix. 353.

[5] Lond. and Edinb. Monthly Journal of Medical Science, April, 1843, p. 298.

[6] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit. by Leidy, ii. 185, Philad., 1849.

[7] Dr. Todd, art. Nervous Centres, in Cyclop. of Anat. and Physiol. Pt. xxv. p. 664, Lond., 1844.

[8] Lectures on Physiology, Zoology, &c., p. 191, Lond., 1819.

stances, and appears to remain constantly the same. This is the cause, why, in the cat, the weight of the encephalon compared with that of the body has been stated as 1 to 156 by one comparative anatomist; and as 1 to 82 by another; that of the dog as 1 to 305 by one, and as 1 to 47 by another, &c.

The following table, taken chiefly from Haller[1] and Cuvier,[2] exhibits the proportion borne by the encephalon to the rest of the body, in man and certain animals.

Child, 6 years old	1/22	Elephant	1/500
Adult	1/35	Stag	1/290
Gibbon	1/48	Roebuck (young)	1/94
Sapajous, from	1/41 to 1/22	Sheep	1/351 to 1/192
Apes	1/48 to 1/24	Ox	1/750 to 1/860
Baboons	1/104 to 1/66	Calf	1/219
Lemurs	1/84 to 1/61	Horse	1/700 to 1/400
Bat (vespertilio)	1/96	Ass	1/254
Mole	1/36	Dolphin	1/25, 1/36, 1/66, 1/102
Bear	1/265	Eagle	1/260
Hedgehog	1/168	Goose	1/360
Fox	1/205	Cock	1/25
Wolf	1/230	Canary Bird	1/14
Beaver	1/290	Humming Bird[3]	1/11
Hare	1/228	Turtle	1/5688
Rabbit	1/140 to 1/152	Tortoise	1/2240
Rat	1/76	Frog	1/172
Mouse	1/43	Shark	1/2496
Wild Boar	1/672	Pike	1/1305
Domestic do.	1/512 to 1/412	Carp	1/560

In 9 males, between 27 and 50 years of age, who died immediately, or within a few hours, after accidents, and other external causes of death, and who had been previously in good health, Dr. John Reid[4] obtained the following results;—the weight used being avoirdupois:—

Average weight of body (9 weighed)	134 lbs. 3½ oz.
Average of encephalon (6 weighed)	3 lbs. 4 oz. 4⅜ dr.
Average of cerebellum (4 weighed)	5 oz. 7¼ dr.
Average of cerebellum with pons and medulla (5 weighed)	6 oz. 6 dr.
Or, taking the average of the four cases only in which the cerebellum was taken	6 oz. 7⅜ dr.
Average of heart (9 weighed)	12 oz. 6 dr.

Relative weight of body to encephalon (6 weighed)	as 1 to 40⅛
Relative weight of body to heart (9 weighed)	as 1 to 173⅓
Relative weight of encephalon to cerebellum (4 weighed)	as 1 to 9⅜
Relative weight of encephalon to cerebellum, with pons and medulla (5 weighed)	as 1 to 8 6/19

[1] Element. Physiol., x. sect. 1. [2] Leçons d'Anat. Comp., ix. art. 5.
[3] On the authority of ex-President Madison.
[4] Lond. and Edinb. Monthly Journal of Med. Science, April, 1843, p. 322.

M. Bourgery[1] found, that the mean weight of the encephalon being 20393·5 grains troy, the cerebral hemispheres weigh 16940·46 grains; the cerebellum, 2176·7 grains; the cephalic prolongation of the cerebro-spinal axis, 1312·2 grains; of which the optic thalami and corpora striata make 879·9 grains; the medulla oblongata with the pons Varolii 432·2 grains; and the spinal cord 710·1 grains. Hence, in man, the cerebral hemispheres include a nervous mass, which is four times greater than the rest of the cerebro-spinal mass; nine times greater than the cerebellum; thirteen times greater than the cephalic stem of the spinal cord; and twenty-four times greater than the spinal cord itself.

It has been the general belief, that the brain of the negro is inferior to that of the white variety of the species; but certain observations of M. Tiedemann led him to the belief, that there is no perceptible difference either in its average weight or average size in the two varieties, and that the nerves compared with the size of the brain are not larger in the former than in the latter. In the external form of the brain of the negro a very slight difference only could be traced; and he affirmed further, that there is absolutely no difference in its external structure, nor does the negro brain exhibit any greater resemblance to that of the ourang outang than the brain of the European, excepting, perhaps, in the more symmetrical disposition of its convolutions. Tiedemann's observations were made, however, upon few subjects; and his own facts do not bear out all his deductions. He admits, that the anterior part of the hemispheres was something narrower than is usually the case in Europeans, "which,"—says Dr. Combe,[2]—"as the anterior portion is the seat of intellect, is really equivalent to conceding that the negro is naturally inferior in intellectual capacity to the European!" M. Tiedemann established that the average capacity of the Ethiopian skull is somewhat less than that of the European, and that a large sized skull is considerably less frequent among them than among any other races of mankind.[3]

The following table, drawn up by Dr. Morton,[4] exhibits the absolute capacity of the cranium or bulk of the brain in cubic inches, obtained by filling the cavity of the crania with leaden shot, one-eighth of an inch in diameter, in different races and families of man.[5] It sufficiently exhibits how little can be judged, in this manner, of their relative intellectual aptitudes.

[1] Lond. Med. Gaz., Jan., 1845, p. 462.

[2] Phrenological Journal, No. liv., Dec., 1837.

[3] Brit. and For. Med. Rev., for Oct., 1839, p. 379.

[4] Catalogue of Skulls of Man and the Inferior Animals in the collection of Samuel George Morton, M.D., &c., 3d edit., p. viii., Philad., 1849.

[5] For the ingenious process invented by Mr. J. S. Phillips, of Philadelphia, by which these measurements were taken, see Dr. Morton's Crania Americana, p. 253, Philad. and Lond., 1839.

TABLE,

Showing the Size of the Brain in cubic inches, as obtained from the measurements of 623 Crania of various Races and Families of Man.

(N. B.—I. C. means Internal Capacity.)

RACES AND FAMILIES.	No. of Skulls.	Largest. I. C.	Smallest. I. C.	Mean.	Mean.
MODERN CAUCASIAN GROUP.					
TEUTONIC FAMILY.					
Germans,	18	114	70	90	92
English,	5	105	91	96	
Anglo-Americans,	7	97	82	90	
PELASGIC FAMILY. *Persians, Armenians, Circassians,*	10	94	75	84	
CELTIC FAMILY. *Native Irish,*	6	97	78	87	
INDOSTANIC FAMILY. *Bengalees, &c.,*	32	91	67	80	
SEMITIC FAMILY. *Arabs,*	3	98	84	89	
NILOTIC FAMILY. *Fellahs,*	17	96	66	80	
ANCIENT CAUCASIAN GROUP.					
From the Catacombs. PELASGIC FAMILY. *Græco-Egyptians,*	18	97	74	88	
From the Catacombs. NILOTIC FAMILY. *Egyptians,*	55	96	68	80	
MONGOLIAN GROUP.					
CHINESE FAMILY,	6	91	70	82	
MALAY GROUP.					
MALAYAN FAMILY,	20	97	68	86	85
POLYNESIAN FAMILY,	3	84	82	83	
AMERICAN GROUP.					
TOLTECAN FAMILY.					79
Peruvians,	155	101	58	75	
Mexicans,	22	92	67	79	
BARBAROUS TRIBES. *Iroquois, Lenapé, Cherokee, Shoshoné, &c.,*	161	104	70	84	
NEGRO GROUP.					
NATIVE AFRICAN FAMILY,	62	99	65	83	83
AMERICAN-BORN NEGROES,	12	89	73	82	
HOTTENTOT FAMILY,	3	83	68	75	
ALFORIAN FAMILY. *Australians,*	8	83	63	75	

From this table it appears, that the smallest mean cranial capacity is found in the Hottentots and Australians, which is 75 cubic inches; whilst that of the Teutonic races is 92 cubic inches. It may be interesting to add, that from the examination of four skulls of the Engé-ena, a quadrumanous animal—Troglodytes *gorilla* of Savage—from Gaboon in Africa, Dr. Jeffries Wyman[1] found the mean capacity, measured according to the method employed by Dr. Morton, to be 28·9½ cubic inches, or considerably less than one-half the mean of the Hottentots and Australians, who afford the minimum average for the human family. The mean cranial capacity of three adult Chimpanzées was even less, or 24 cubic inches.

Wrisberg and Sömmering[2] proposed another point of comparison—the ratio of the mass of the encephalon to that of the rest of the nervous system; and they asserted, that in proportion as any animal possesses a larger share of the former; or, in other words, in proportion as the percipient and intellectual organ exceeds the other or the organ of the external senses—the mental sphere may be expected to be more diversified and developed. But although man is, in general, pre-eminent in this respect, he is not absolutely so. It would be still more important to know the ratio, which the cerebrum or brain proper bears to the cerebellum and medulla oblongata. The first is essentially the organ of intellect; and the most striking character of the human brain is the large developement of the cerebral hemispheres, of which we have no parallel in the animal kingdom. The last is the encephalic part in which the nerves of sense arise or terminate.

Fig. 134.

Facial Line and Angle of Man.

The assertion, that man has the largest cerebrum in proportion to the cerebellum, is not accurate. The Wenzels[3] found the ratio, in him, to be as $6\frac{51}{129}$ or $8\frac{42}{121}$ to 1; in the horse, $4\frac{1}{2}$ to 1; in the cow, $5\frac{173}{211}$ to 1; in the dog, $6\frac{4}{29}$ to 1; in the cat, $4\frac{4}{18}$ to 1; in the mole, $3\frac{2}{3}$ to 1; and in the mouse, $6\frac{2}{3}$ to 1. Nor is it true that man has the largest cerebrum in proportion to the medulla

[1] A description of two additional Crania of the Engé-ena, &c., read before the Boston Society of Natural History, Oct. 3, 1849; and published in the American Journal of Science and Arts, second series, vol. ix.

[2] Corpor. Human. Fabric. iv. § 92; and Blumenbach's Comp. Anat. by Lawrence, p. 292, Lond., 1807.

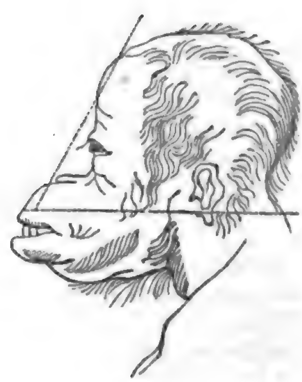
[3] De Penitiori Structur. Cerebr. Hominis et Brutorum, tab. iv.

oblongata and medulla spinalis; although to this position there are perhaps fewer objections than to the others. None of them, it is obvious, are distinctive between man and animals, or assist us in solving the great problem of the source and seat of the numerous psychological differences we observe.

Various plans have been devised for appreciating the comparative size of the cranium,—which is generally in a ratio with that of the brain,—and of the bones of the face. As the former contains the organ of the intellect, and the latter those of the external senses and of mastication, it has been presumed, that the excess of the former would indicate the predominance of thought over sense; and, conversely, that the greater developement of the face would place the animal lower in the scale.

One of these methods, first proposed by Camper,[1] is by taking the course of the *facial line*, and the amount of the *facial angle*. The *facial line* is a line drawn from the projecting part of the forehead to the alveoli of the incisor teeth of the upper jaw; the *facial angle* is that formed between this line and another drawn horizontally backwards from the upper jaw. The course of the horizontal line and its point of union with the facial line are not uniform in all the figures given by Camper: sometimes, it is made to pass through the meatus auditorius externus; but it often falls far below it; yet Dr. Bostock thinks[2] "we cannot hesitate to admit the correctness of Camper's observations, and we can scarcely refuse our assent to the conclusion that he deduces from them." In man, whose face is situate perpendicularly under the cranium, the facial angle is very large. In animals, the face is placed in front of the cranium; and as we descend from man the angle becomes less and less, until it is finally lost; the cranium and face being in most reptiles and fish on a level. The marginal figure (Fig. 134) exhibits the difference between the facial angle of those of European descent, and that of the negro. By covering with the finger the parts below the nose alternately, we have the countenance of the white, and negro, in which the facial angle differs as much as 10°, or 15°. Fig. 135 exhibits the facial line and angle of the ourang-outang. Animals that have the snout long, and the facial angle consequently small, have been proverbially esteemed foolish,[3]—such are the snipe, stork, crane, &c.; whilst superior intelligence has been ascribed to those in which the angle is more largely developed,—as the elephant and the owl; although in them, the large facial angle is caused by the size of the frontal sinuses, or

Fig. 135.



Facial Line and Angle of the Ourang-Outang.

[1] Dissertation Physique de M. Camper, sur les Differences Réelles que presentent les Traits du Visage, &c., traduit du Hollandois, par D. B. Q. Disjonval, Autrecht, 1791.

[2] Physiology, 3d edit., p. 804, Lond., 1836.

[3] Lawrence, op. citat., p. 168.

by the wide separation between the two tables of the skull, and is necessarily no index of the size of the brain. Yet, from this cause, perhaps, the owl was chosen as an emblem of the goddess of wisdom; and the elephant has received a name in the Malay language, indicating an opinion, that he is possessed of reason. The following table exhibits the facial angle in man and certain animals, taken by a line drawn parallel to the floor of the nostrils, and meeting another, drawn from the greatest prominence of the alveoli of the upper jaw to the prominence of the forehead:—

Man	68° to 88° or more	Polecat	31°
Sapajou	65°	Pug dog	35°
Ourang-outang	56° or 58°	Mastiff	41°
Guenon	57°	Hare	30°
Mandril	30° to 42°	Ram	30°
Coati	28°	Horse	23°

The facial angle may, then, exhibit the difference between man and animals; and, to a certain extent, between the species or individuals of the latter; but, farther, it is of little or no use.[1] In man, it may be considered to vary from 70° to 85° in the adult; but in children it reaches as high as 90° and upwards; a sufficient proof, that it cannot be regarded as a measure of the intellect. In the European, it has been estimated, on the average, at perhaps, 80°, in the Mongol, 75°, and in the negro, 70°, not many degrees above the Sapajou.[2]

The following table, drawn up from the average of actual measurements of the skulls of different races and families of man, in the collection of Dr. Morton,[3] will afford more precise information on this matter.

	FACIAL ANGLE.		
	Average.	Highest.	Lowest.
Arab (2 cases)	82	88	76
European and Anglo-American	80	85	77
Egyptian	79·3	86	73
Bengalee	79·3	83	76
Circassian	78·5	81	75
Sandwich Islander (one case)	78		
Chinese (one case)	78		
Guanche (one case)	77		
Negro	76·8	83	69
Indian	76·1	84	70
Hottentot (one case)	75		
Peruvian	74·9	81	68
Malay	74·6	82	69

It is found, that the skulls of different nations, and of individuals of the same nation, may agree in the facial angle, whilst there may be striking distinctions in the shape of the cranium and face, in the air and character of the whole head; as well as in the particular features,—the inclination of the facial line being more dependent on the prominence of the upper jaw and frontal sinuses than on the general form of

[1] Dr. Morton, in his splendid work, Crania Americana, Philad., 1839, describes a "Facial Goniometer," originally suggested by Dr. Turnpenny, of Philadelphia, which is admirably adapted for measuring the facial angle.

[2] Prichard's Physical History of Mankind, i. 288, 3d edit., Lond., 1836.

[3] Catalogue of Skulls of Man, &c., 3d edit., Philad., 1849.

the head. The ancients were impressed with the intellectual air exhibited by the open facial angle; for we find in all their statues of legislators, sages, and poets, an angle of at least 90°, and in those of heroes and superhuman natures it is as high as 100°. This angle, according to Camper, never existed in nature; and yet he conceives it to be the *beau idéal* of the human countenance, and to have been the ancient model of beauty. It was, more probably, the model of superior intellectual endowment, although ideas of beauty might have been connected with it. Every nation forms its notions of beauty, derived from this source, chiefly from the facial angle to which it is accustomed. With the Greeks it was large, and therefore the vertical facial line was highly estimated. For the same reason, it is pleasing to us; but such would not be the universal impression. Savage tribes on our own continent, have preferred the pyramidal shape of the head, and made use of every endeavour, by unnatural compression in early infancy, to produce it; whilst others, not satisfied with the natural shape of the frontal bone, have forced back the forehead, either by applying a flat piece of board to it, like the Indians of our own continent, or by iron plates, like the inhabitants of Arracan. By this practice the Caraibs are said to be able to see over their heads.

M. Daubenton,[1] again, endeavoured, by taking the *occipital line* and *angle*, to measure the differences between the skulls of man and animals. A line is drawn from the posterior margin of the foramen magnum of the occipital bone to the inferior margin of the orbit, and another from the top of the head to the space between the occipital condyles. In man, these condyles, as well as the foramen magnum, are so situate, that a line drawn perpendicular to them will be a continuation of the vertebral column; but in animals they are placed more or less obliquely; the perpendicular will, therefore, necessarily be thrown farther forward, and the angle be rendered more acute.[2] Blumenbach says, that Daubenton's method may be adapted to measure the degrees of comparison betwixt man and brutes, but not varieties of national character; for he found it even different in the skulls of two Turks, and three Ethiopians. The methods of Camper and Daubenton combined, were, also, insufficient to indicate the varieties in national and individual character. He accordingly describes a new method,—which he calls *norma verticalis*.[3] It consists in selecting two bones; the frontal from those of the cranium, and the superior maxillary from those of the face; comparing these with each other, by regarding them vertically, placing the great convexity of the cranium directly before him, and marking the relative projections of the maxillary bone beyond the arch of the forehead. The Asiatic Georgian is found to be characterized by the great expanse of the upper and outer part of the cranium,

[1] Mémoires de l'Académie des Sciences de Paris, p. 568, Paris, 1764.

[2] By some writers, Daubenton's method is said to consist of "a line drawn from the posterior margin of the occipital foramen to the inferior margin of the orbit; and another drawn horizontally through the condyles of the occipital bone." It is obvious, that little or no comparative judgment of the cranium and face could be formed from this.

[3] Decad. Collectionis suæ Craniorum diversarum Gentium; and De Gener. Human. Var. Nativ., edit. 3a, Gotting., 1795.

which hides the face. In the Ethiopian, the narrow, slanting forehead permits the face to appear, whilst the cheeks and jaws are compressed laterally and elongated in front; and in the Tungoose, the maxillary, malar, and nasal bones are widely expanded on each side; and the two last rise to the same horizontal level with the space between the frontal sinuses—the glabella. Blumenbach's method, however, only affords us the comparative dimensions of the two bones in one direction. It does not indicate the depth of either, or their comparative areas. The view thus obtained is, therefore, partial.

Finding the inapplicability of other methods to the greater part of the animal creation—to birds, reptiles, and fishes, for example—M. Cuvier[1] suggested a comparison between the areas of the face and cranium under the vertical section of the head. The result of his observations is—that, in the European, the area of the cranium is four times that of the face, excluding the lower jaw. In the Calmuck, the area of the face is one-tenth greater than in the European; in the negro, one-fifth, and in the sapajou, one-half. In the mandril, the two areas are equal; and, in proportion as we descend in the scale of animals, the area of the face gains over that of the cranium; in the hare, it is one-third greater; in the ruminant animals double; in the horse, quadruple, &c.; so that the intelligence of the animal appeared to be greater or less as the preponderance of the area of the face over that of the skull diminished or increased.

The truth, according to Sir Charles Bell,[2] is, that the great difference between the bones of the cranium and face in the European and negro is in the size of the jaw-bones. In the negro, these bear a much greater proportion to the head and to the other bones of the face than in the European; and the apparent size of the bones of the negro face was discovered to proceed solely from the size and shape of the jaw-bones; whilst the upper bones of the face, and, indeed, all that had no relation to the teeth and to mastication, were less than those of the European skull.

Other methods, of a similar kind, have been proposed by naturalists, as Spigel,[3] Herder,[4] Mulder,[5] Walther,[6] Doornik,[7] Spix,[8] and Oken, but they are all insufficient to enable us to arrive at a satisfactory comparison.[9] Blumenbach asserts, that he found the facial and occipital angles nearly alike in three-fourths of known animals.

[1] Leçons d'Anatomie Compar., No. viii. art. i. tom. ii. p. 1.

[2] Anatomy of Expression, 3d edit., Lond., 1844.

[3] Lineæ Cephalometricæ Spigelii, in Spigel, De Human. Corpor. Fabric., i. 8.

[4] Nackenlinien (Lineæ nuchales Herderi), in Herder's Ideen zur Philosophie der Geschichte der Menschheit, Th. iii. s. 186, Tübing., 1806.

[5] Vorderhauptwinkel (Angulus sincipitalis Mulderi), in art. Kopflinien, in Pierer's Anat. Physiol. Real Wörterb., iv. 524, Leipz., 1821.

[6] Schädelwinkel (Angulus Cranioscopicus Waltheri), in Walther, Kritische Darstellung der Gallschen Anat. Physiol. Untersuch. des Gehirn und Schädelbaues, s. 108, Zürich, 1802.

[7] Wijsgeerig Natuurkundig Onderzoek aangande den Oorspronglijken Mensch en de Oorspronglike Stammen van deszelfs Geslacht, Amsterd., 1808.

[8] Cephalogenesis, Monach., 1815.

[9] Oken, Lehrbuch der Zoologie, Abth. ii. s. 660. A description of all these methods is given by Choulant, in Pierer, loc. cit.

Moreover, it by no means follows, that, in the same species, there should be a correspondence between the size of the cranium and face. In the European, the face may be unusually large; and yet the mental endowments may be brilliant. Leo X., Montaigne, Leibnitz, Racine, Haller, Mirabeau, and Franklin, had all large features.[1]

All these methods, again, are confined to the estimation of the size of the whole encephalon; whereas the brain, we have seen, is alone concerned in the intellectual and moral manifestations; although Gall includes the cerebellum. It has already been remarked, that no animal equals man in the developement of the cerebral hemispheres. In the ape they are less prominent; and below it in the scale of creation, they become less and less; the middle lobes are less arched downwards; and the posterior lobes are ultimately wanting, leaving the cerebellum uncovered; the convolutions are less and less numerous and deep, and the brain at length is found entirely smooth. The experiments of Rolando of Turin, and Flourens[2] of Paris, are likewise confirmatory of this function of the brain proper. These gentlemen experimented upon different portions of the encephalon, with the view of detecting their functions;—endeavouring, as much as possible, not to implicate any part except the one which was the subject of investigation; and they found, that if the cerebral hemispheres were alone removed, the animal was thrown into a state of stupor or lethargy; was insensible to all impressions; to every appearance asleep, and evidently devoid of all intellectual and affective faculties. On the other hand, when other parts of the encephalon were mutilated—the cerebellum, for example—leaving the cerebral hemispheres uninjured, the animal was deprived of certain other faculties—that of moving, for instance—but retained its consciousness, and the exercise of all its senses.

M. Desmoulins,[3] in his observations on the nervous system of vertebrated animals, is in favour of a view, embraced by M. Magendie,[4] that the intellectual sphere of man and animals depends exclusively on the cerebral convolutions; and that an examination of the convolutions will exhibit the intellectual differences, not only between different species, but between individuals of the same species. According to him, the cerebral convolutions are numerous in animals in proportion to their intelligence; and, in animals of similar habitudes, have a similar arrangement. In the same species, they differ sensibly, according to the degree in which the individuals possess the qualities of their nature:—for example, they vary in the fœtus and adult; are manifestly less numerous and smaller in the idiot; and become effaced in protracted cases of insanity. He farther remarks, that the morbid conditions of the encephalon, which occasion mental aberration, are especially such as act upon the convolutions; and that whilst apoplectic extravasation into the centre of the organ induces paralysis of

[1] Gall, Sur les Fonctions du Cerveau, ii. 296.
[2] Recherches Expérimentales sur le Système Nerveux, 2de édit., Paris, 1842.
[3] Anatomie des Systèmes Nerveux des Animaux à Vertèbres, Paris, 1825.
[4] Précis Elémentaire, edit. cit., i. 185.

sensation and motion, the slightest inflammation of the arachnoid membrane causes delirium. Hence, he deduces the general principle, that the number and perfection of the intellectual faculties are in a ratio with the extent of the cerebral surfaces. It would seem, however, from some experiments by M. Baillarger,[1] that the amount of intellectual developement in man, and in the various classes of animals, is far from being proportionate to the extent of surface presented by the brain of each. That of man, for instance, has, in proportion to its volume, a much less extent of surface than the brains of the lower mammalia; and the brain of the rabbit has, in proportion to its volume, an extent of surface two and a half times greater than that presented by the brain of man.

The view of M. Desmoulins, so far as regards the seat of the intellectual and moral faculties, accords with one to which attention must now be directed; and which has given rise to more philosophical inquiry, laborious investigation, and, it must be admitted, to more idle enthusiasm and intolerant opposition, than any of the psychological doctrines advanced in modern times: we allude to the views of M. Gall.[2] These are, 1st, That the intellectual and moral faculties are innate. 2dly, That their exercise or manifestation is dependent upon organization. 3dly, That the encephalon is the organ of all the appetites, feelings, and faculties; and, 4thly, That the encephalon is composed of as many particular organs as there are appetites, feelings, and faculties, differing essentially from each other.

The importance of Gall's propositions; the strictly physiological direction they have taken—the only one, as we have said, which appears likely to aid us in our farther acquaintance with the psychology of man—require that the physiological student should have them placed before him as they emanated from the author. The work of Gall on the functions of the encephalon comprises, however, six octavo volumes, not distinguished for unusual method or clearness of exposition. Fortunately, the distinguished biologist, M. Adelon, to whom we have so frequently referred, has spared us the necessity of a tedious and difficult analysis, by the excellent and impartial view he has given in the *Dictionnaire de Médecine*,[3] which has since been transferred to his *Physiologie de l'Homme;* both being abridgments of the *Analyse d'un Cours du Dr. Gall*, published by him in 1808.

The foundation of this doctrine is, that the encephalon is not a single organ, but is composed of as many nervous systems as there are primary and original faculties of the mind. In the view of Gall, it is a group of several organs, each of which is concerned in the production of a special moral act; and, according as the encephalon of an animal contains a greater or less number of organs, and of a greater or less degree of developement, the animal has, in its moral sphere, a greater or less number of, or more or less active, faculties. In like

[1] Revue Médicale, Mai, 1845.
[2] Sur les Fonctions du Cerveau, Paris, 1825.
[3] Art. Encéphale (Physiologie), Paris, 1823, and art. Facultés de l'Esprit et de l'Ame, &c., in Dict. de Médecine, viii. 469, Paris, 1823.

manner, as there are as many sensorial nervous systems and organs of sense as there are external senses, so there are, it is maintained, as many encephalic nervous systems as there are special moral faculties or internal senses. Each moral faculty has, in the encephalon, a nervous part concerned in its production; as each sense has its special nervous system; the sole difference being, that the nervous systems of the senses are separate and distinct, whilst those of the encephalon are crowded together in the small cavity of the cranium, and appear to form but one mass.

The proofs, adduced by Gall[1] in favour of his proposition, are the following:—1st. It has been established as a principle, that differences in the psychology of man and animals correspond to varieties in the structure of the encephalon, and that the latter are dependent on the former. Now, differences of the encephalon consist less in changes of the general form of the organ, than in parts, which are present in some and not in others; and if the presence or absence of such parts is the cause why certain animals have a greater or less number of faculties than others, they ought certainly to be esteemed special organs of such faculties. 2dly. The intellectual and moral faculties are multiple. This every one admits. Each, consequently, ought to have its special organ; and the admission of a plurality of intellectual moral faculties must induce that of a plurality of encephalic organs, in the same manner as each external sense has its proper nervous system. 3dly. In different individuals of the same species,—in different men,—much psychological variety is observable. The cause of this is doubtless in the encephalon; but we can hardly ascribe it to a difference in the general shape of the organ, which is sensibly the same. It is owing rather to differences in its separate parts. Are not such parts, therefore, he asks, distinct nervous systems? 4thly. In the same individual—in the same man—the intellectual and affective faculties have never the same degree of activity: whilst one predominates, another may be feeble. Now, this fact, which is inexplicable under the hypothesis, that the encephalon is a single organ, is readily intelligible under the theory of the plurality of organs. Whilst the encephalic part, which is the agent of the one faculty, is proportionably more voluminous or more active, that which presides over the other is less so. Why, he asks, may not this happen with the encephalic organs, as with the other organs of the body,—the senses, for example? Cannot one of these be feeble, and the other energetic? 5thly. In the same individual, all the faculties do not appear, nor are they all lost at the same period. Each age has its own psychology. How can we explain these intellectual and moral varieties according to age, under the hypothesis that the encephalon is a single organ? Under the doctrine of the plurality of encephalic organs, the explanation is simple. Each encephalic system has its special period of developement and decay. 6thly. It is a common observation, that when we are fatigued by one kind of mental occupation, we have recourse to another; yet it often happens, that the new labour, instead of adding to the fatigue experienced by

[1] Op. cit., ii. 394.

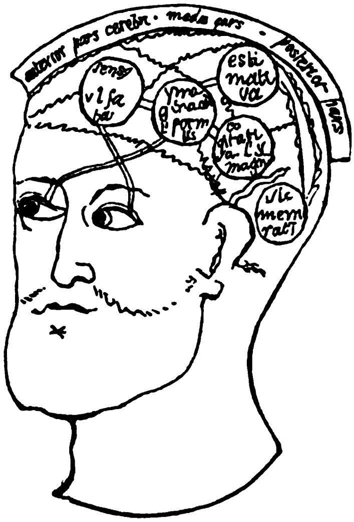
the former, is a relaxation. This, Gall remarks, would not be the case if the encephalon were a single organ, and acted as such; but it is readily explicable under the doctrine of plurality of organs. It is owing to a fresh encephalic organ having been put in action. 7thly. Insanity is frequently confined to one single train of ideas, as in the variety called *monomania*, which is often caused by the constancy and tenacity of an original exclusive idea. This is frequently removed by exciting another idea opposed to the first, which distracts attention from it. Is it possible, Gall asks, to comprehend these facts under the hypothesis of unity of the encephalon? 8thly. Idiocy and dementia are often only partial, and it is not easy to conceive, under the idea of the unity of the encephalon, how one faculty remains amidst the abolition of all the others. 9thly. A wound or a physical injury of the encephalon frequently modifies but one faculty, paralyzing, or augmenting it, and leaving every other uninjured. 10thly, and lastly. Gall invokes the analogy of other nervous parts; and, as the great sympathetic, medulla oblongata, and medulla spinalis are—in his view at least—groups of special nervous systems, it is probably, he says, the same with the encephalon.

Such are the main arguments employed by Gall for proving, that the encephalon consists of a plurality of organs, each of which is concerned in the production of a special intellectual or moral faculty; and should they not carry conviction, it must be admitted that many of them are ingenious and forcible, and all merit attention.

It is a prevalent idea, that this notion of a plurality of organs is a fantasy, which originated with Gall. Nothing is more erroneous: he has adduced the opinions of numerous writers who preceded him, some of whom have given figures of the cranium, with the seats of the different organs and faculties marked upon it. To this list might be added numerous others. Aristotle, in whose works are found the germs of many discoveries and speculations, thought that the first or anterior ventricle of the brain, was the ventricle of *common sense;* because, from it, according to him, the nerves of the five senses branched off. The second ventricle, connected by a minute opening with the first, he designated as the seat of *imagination*, *judgment*, and *reflection;* and the third, as a storehouse into which the conceptions of the mind, digested in the second ventricle, were transmitted for retention and accumulation: he regarded it as the seat of *memory*. Bernard Gordon, in a work written in 1296, gives nearly the same account of the brain. It contains, he says, three cells or ventricles. In the anterior part of the first lies *common sense;* the function of which is to take cognizance of the various forms and images received by the several senses. In the posterior part of the first ventricle he places *phantasia;* and in the anterior part of the second, *imaginativa;* in the posterior part of the middle lies *estimativa*. It would be a waste of time and space, to adduce the absurd notions entertained by Gordon on this subject. He thinks there are three faculties or virtues—*imaginatio*, *cogitatio*, and *memoria*—each of which has a special organ engaged in its production.

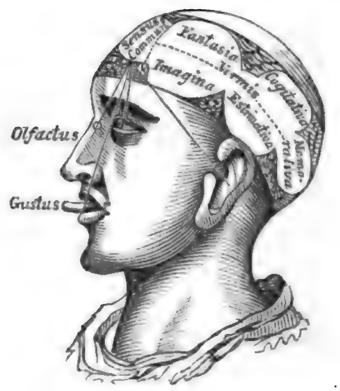
For many centuries it was believed, that the cerebrum was the organ of *perception*, and the cerebellum that of *memory*. Albert the Great, in the thirteenth century, sketched a head on which he represented the seat of the different intellectual faculties. In the forehead and first ventricle he placed *common sense* and *imagination;* in the second *intelligence* and *judgment;* and in the third, *memory* and the *motive force*. The head in the margin (Fig. 136), is from an old sketch contained in the *Book Rarities* of the University of Cambridge. Servetus conceived, that the two anterior cerebral cavities are for the reception of the images of external objects; the third is the seat of thought; the aqueduct of Sylvius, the seat of the soul; and the fourth ventricle that of memory. In 1491, Peter Montagnana published an engraving, in which were represented the seat of the *sensus communis*, a *cellula imaginativa*, *cellula estimativa* seu *cogitativa*, a *cellula memorativa*, and a *cellula rationalis*. A head by Ludovico Dolci exhibits a similar arrangement. (Fig. 137.)[1]

Fig. 136.



Old Phrenological Head.

Fig. 137.



Phrenological Head by Dolci, A. D. 1562.

The celebrated Dr. Thomas Willis, in 1681, asserted, that the corpora striata are the seat of perception; the medullary part of the brain that of *memory* and *imagination;* the corpus callosum that of *reflection;* and the cerebellum furnished the vital spirits necessary for the involuntary motions.[2] It would appear, too, that Swedenborg, half a century before the promulgation of Gall's theory, maintained the doctrine, that every man is born with a disposition to all sorts of evil, which must be checked by education, and, as far as possible, rooted out; and that the degree of success or failure in this respect would be indicated by the shape of the skull. "The peculiar distinctions of man, will and the understanding," he argued, "have their seats in the brain, which is excited by the fleeting desires of the will, and the ideas of the intellect. Near

[1] See Burton's Anatomy of Melancholy, 11th edit., i. 32, Lond., 1813; and Margarita Philosophica, lib. ix. cap. 40, Basil., 1508, cited by Dr. John Redman Coxe, in Dunglison's American Medical Intelligencer, i. 58, Philad., 1838.

[2] Gall, Sur les Fonctions du Cerveau, ii. 350, Paris, 1835.

the various spots where these irritations produce their effects, this or that part of the brain is called into a greater or less degree of activity, and forms along with itself corresponding parts of the skull."[1] This view, that exercise of the encephalic organs occasions their developement in bulk, and want of due exercise their decrease, is now maintained by many phrenologists; but denied by others.

The above examples are sufficient to show, that the attempt to assign faculties to different parts of the brain; and, consequently, the belief, that the brain consists of a plurality of organs, had been long indulged by anatomists and philosophers. The views of Gall are resuscitations of the old; but resembling them little more than in idea. Those of the older philosophers were the merest fantasies, unsupported by observation: the speculations of the modern physiologist have certainly been the result of long and careful investigation, and deep meditation. Whilst, therefore, we may justly discard the former, the latter are worthy of careful and unprejudiced examination.

Admitting, with M. Gall, the idea of the plurality of organs in the encephalon, the inquiry would next be,—how many special nervous systems are there in that of man, and what are the primary intellectual and moral faculties over which they preside? This Gall has attempted. To attain this double object, he had two courses to adopt;—either, first to indicate anatomically the nervous systems that constitute the encephalon; and then to trace the faculties of which they are the organs; or, contrariwise, to point out first the primary faculties, and afterwards to assign to each an organ or particular seat. The first course was impracticable. The encephalic organs are not distinct, isolated: and if they were, simple inspection could not indicate the faculty over which they preside, any more than the appearance of a nerve of sense could indicate the kind of sensation for which it is destined. It was, only, therefore, by observing the faculties, that he could arrive at a specification of the primary encephalic organs. But here, again, a source of difficulty arose. How many primary intellectual and moral faculties are there in man? and what are they? The classifications of the mental philosophers,—differing, as we have seen they do, so intrinsically and essentially from each other,—could lead him to no conclusion. He first, however, followed the views on which they appeared to be in accordance; and endeavoured to find particular organs for the faculties of *memory*, *judgment*, *imagination*, &c. But his researches in this direction were fruitless. He, therefore, took for his guidance the common notions of mankind; and having regard to the favourite occupations, and different vocations of individuals, to those marked dispositions, which give occasion to the idea, that a man is born a *poet*, *musician*, or *mathematician*, he carefully examined the heads of such as presented these predominant qualities, and endeavoured to discover in them such parts of the encephalon as were more prominent than usual, and might be considered as special nervous systems,—organs of those faculties. After multitudinous empirical researches on living individuals, on collections of crania, and casts

[1] Dr. Sewall, Examination of Phrenology, 2d edit., p. 14, Boston, 1839.

made for the purpose; attending particularly to the heads of such as had one of their faculties predominant, and who were, as he remarks, *geniuses* on one point,—to the maniac, and the monomaniac;—after a sedulous study, likewise, of the heads of animals, comparing especially those that have a particular faculty with such as have it not, in order to see if there did not exist in the encephalon of the former some part which was wanting in that of the latter; by this entirely experimental method, he ventured to specify, in the encephalon of animals and man, a certain number of organs; and, in their psychology, as many faculties, truly primary in their character.

But, in order that such a mode of investigation be applicable it must be admitted, 1st. That one of the elements of the activity of a function is the developement of its organ. 2dly. That the encephalic organs end, and are distinct, at the surface of the encephalon. 3dly. That the cranium is moulded to the encephalon, and is a faithful index of its shape; for it is, of course, through the skull and the integuments covering it, that Gall attempts, in the living subject, to appreciate the state of the encephalon.

Within certain limits, these positions are true. In the first place, we judge of the activity of a function, by the size of the organ that executes it: the greater the optic nerve, the more acute we expect to find the sense of sight. In the second place, according to the anatomical theory of Gall, the encephalic convolutions are the final expansions of the encephalon: if we trace back the original fasciculi, which, by their terminations, form the hemispheres of the brain, they are observed to increase gradually in size in their progress towards the circumference of the organ, and to end in the convolutions. Lastly, to a certain extent the cranium is moulded to the encephalon; and participates in all the changes which the latter undergoes at different periods of life and in disease. For example, during the first days after the formation of the encephalon of the fœtus, the cranium is membranous, and has exactly the shape of that viscus. On this membrane, ossific points are deposited, so that, when the membrane has become bone, the cranium has still the shape of the encephalon. In short, nature having made the skull to contain the encephalon has fitted the one to the other, and this so accurately, that its internal surface exhibits sinuosities corresponding to the vessels that creep on the surface; and digitations corresponding to the encephalic convolutions. The encephalon, in fact, rigidly regulates the ossification of the cranium; and when, in the progress of life, it augments, the capacity of the cranium is augmented likewise; not by the effect of mechanical pressure, but owing to the two parts being catenated in their increase and nutrition. This remark applies not only to the skull and encephalon, regarded as a whole, but to their separate parts. Certain portions of the encephalon are not developed simultaneously with the rest of the organ; and the same thing happens to the portions of the skull that invest them. The forehead, for example, begins to be developed after the age of four months; but the inferior occipital fossæ do not increase in proportion until the period of puberty. Again; when the encephalon fades and wastes in advanced life, the cavity of the cranium contracts, and its ossification

takes place on a less and less outline. In advanced life, however, according to Gall, the correspondence between the encephalon and the inner table of the skull is alone maintained; the table appearing to be a stranger to all nutritive movement, and preserving its dimensions. Lastly, the cranium partakes of all the variations experienced by the encephalon in disease. If the latter be wanting, as in the acephalous monster, the cranium is wanting also. If a portion of the encephalon exists, the corresponding portion of the cranium exists. If the encephalon is smaller than natural, as in the idiot, the cranium is also. If, on the contrary, it is distended by hydrocephalus, the cranium has a considerable capacity: and this, not owing to a separation, at the sutures, of the bones composing it, but to ossification taking place on a larger outline. If the encephalon be much developed in any one part, and not in another, the cranium is protuberant in the former; restricted in the latter; and lastly, in cases of mania, the cranium is often affected, being, for example, unusually thick, dense, and heavy.

These reasons, adduced by Gall, may justify the admission, that, within certain limits, the skull is moulded to the encephalon; and, if this be conceded, the method followed by him of specifying the organs of the mental faculties may be conceived practicable.

Such is the basis of the system of *craniology* proposed by Gall. It has also been called *cranology*, *organology*, *phrenology*, and *cranioscopy:* although, strictly speaking, it is by *cranioscopy* that we acquire a knowledge of *craniology*,—the art of prejudging the intellectual and moral aptitudes of man and animals, from an examination of the cranium. It is, of course, limited in its application. Gall admits, that it is not available in old age, owing to the physiological fact before stated,—that the external table of the skull is no longer modified by the changes, that happen to the encephalon; and he acknowledges, that its employment is always difficult, and liable to errors. We cannot, for example, touch the cranium directly; for it is covered by hair and integument. The skull is made rough, in parts, by muscular impressions; and these roughnesses must not be confounded with what are termed "*protuberances*,"—prominences, formed by a corresponding developement of the encephalon. In this respect, craniology presents more difficulties in animals, owing to their heads being more covered with muscles, and from the inner table of the skull being, alone, in contact with the encephalon beneath. Other errors may be incurred from the frontal and superior longitudinal sinuses; and from the possible separation of the hemispheres at the median line. The difficulty is, of course, extremely great in appreciating the parts of the encephalon, that are situate behind the eyes; and craniology must be entirely inapplicable to those encephalic organs that terminate at its base.

Gall has taken especial pains to remark, that by craniology we can only prejudge the dispositions of men, not their actions; and can appreciate but one of the elements of the activity of organs—their size,—not what belongs to their intrinsic activity, and to the impulse or spring they may receive from the temperament or general formation. Setting out, however, with the principle, that the predominance of a faculty is in a great measure dependent on the developement of the

portion of the encephalon which is its organ, he goes so far as to particularize, in this developement, what is owing to the length of the encephalic fibres, and what to their breadth; referring the activity of

Fig. 138.

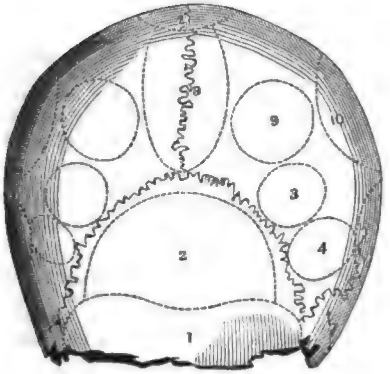


Fig. 139.

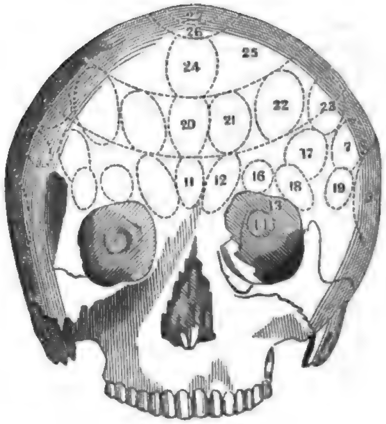
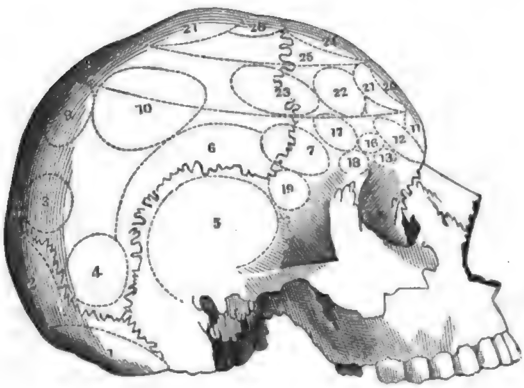


Fig. 140.



Phrenological Organs according to Gall.

the faculty to the former, and its intensity to the latter. In applying cranioscopy to animals, he observes, that the same encephalic organ frequently occupies parts of the head, that seem to be very different, on account of the difference between *station* in animals and man, and of the greater or less number of systems, that compose their encephalon.

The following are the encephalic organs enumerated by Gall, with the corresponding faculties:—the numbers corresponding with those of the above illustrations.

1. *Instinct of generation, of reproduction; amativeness. Instinct of propagation; venereal instinct.* (*German.*) Zeugungstrieb, Fortpflanzungstrieb, Geschlechtstrieb.	Seated in the cerebellum. It is manifested at the surface of the cranium by two round protuberances, one on each side of the nape of the neck.

2. *Love of progeny; philoprogenitiveness.* (G.) Jungenliebe, Kinderliebe.	Indicated at the external occipital protuberance.
3. *Attachment, friendship.* (G.) Freundschaftsinn.	About the middle of the posterior margin of the parietal bone; anterior to the last.
4. *Instinct of defending self and property; love of strife and combat; combativeness; courage.* (G.) Muth, Raufsinn, Zanksinn.	Seated a little above the ears; in front of the last, and towards the mastoid angle of the parietal bone.
5. *Carnivorous instinct; inclination to murder; destructiveness; cruelty.* (G.) Wurgsinn, Mordsinn.	Greatly developed in all the carnivorous animals; forms a prominence at the posterior and superior part of the squamous surface of the temporal bone, above the mastoid process.
6. *Cunning; finesse; address; secretiveness.* (G.) List, Schlauheit, Klugheit.	Above the meatus auditorius externus, upon the sphenoidal angle of the parietal bones.
7. *Desire of property; provident instinct; cupidity; inclination to robbery; acquisitiveness.* (G.) Eigenthumssinn, Hang zu stehlen, Einsammlungssinn, Diebsinn.	Anterior to that of cunning, of which it seems to be a prolongation, and above that of mechanics, with which it contributes to widen the cranium, by the projection which they form at the side of the frontal bone.
8. *Pride; haughtiness; love of authority; elevation.* (G.) Stolz, Hochmuth, Höhensinn, Herrschsucht.	Behind the top of the head, at the extremity of the sagittal suture, and on the parietal bones.
9. *Vanity; ambition; love of glory.* (G) Eitelkeit, Ruhmsucht, Ehrgeitz.	Situate at the side of the last, near the posterior internal angle of the parietal bones.
10. *Circumspection; foresight.* (G.) Behutsamkeit, Vorsicht, Vorsichtigkeit.	Corresponds to the parietal protuberances.
11. *Memory of things; memory of facts; sense of things; educability; perfectibility; docility.* (G.) Sachgedächtniss, Erziehungsfähigkeit, Sachsinn.	Situate at the root of the nose, between the two eyebrows, and a little above them.
12. *Sense of locality; sense of the relation of space; memory of places.* (G.) Ortsinn, Raumsinn.	Answers to the frontal sinuses, and is indicated externally by two prominences at the inner edge of the eyebrows, near the root of the nose, and outside the organ of memory of things.
13. *Memory of persons; sense of persons.* (G.) Personensinn.	At the inner angle of the orbit.
14. *Sense of words; sense of names; verbal memory.* (G.) Wortgedächtniss, Namensinn.	Situate at the posterior part of the base of the two anterior lobes of the brain, on the frontal part of the bottom of the orbit, so as to make the eye prominent.
15. *Sense of spoken language; talent of philology; study of languages.* (G.) Sprachforschungssinn, Wortsinn, Sprachsinn.	Also at the top of the orbit, between the preceding and that of the knowledge of colour.
16. *Sense of the relations of colour; talent of painting.* (G.) Farbensinn.	The middle part of the eyebrows; encroaching a little on the forehead.
17. *Sense of the relations of tones; musical talent.* (G.) Tonsinn.	A little above and to one side of the last; above the outer third of the orbitar arch.
18. *Sense of the relations of numbers; mathematics.* (G.) Zahlensinn.	On the outside of the organ of the sense of the relations of colour, and below the last.

19. *Sense of mechanics; sense of construction; talent of architecture; industry.* (*G.*) Kunstsinn, Bausinn.	A round protuberance at the lateral base of the frontal bone, towards the temple, and behind the organs of music and numbers.
20. *Comparative sagacity.* (*G.*) Vergleichender Scharfsinn.	At the middle and anterior part of the frontal bone, above that of the memory of things.
21. *Metaphysical penetration; depth of mind.* (*G.*) Metaphysischer Tiefsinn.	In part, confounded with the preceding. Indicated, at the outer side of this last, by two protuberances, which give to the forehead a peculiar hemispherical shape.
22. *Wit.* (*G.*) Witz.	At the lateral and outer part of the last; and giving greater width to the frontal prominences.
23. *Poetical talent.* (*G.*) Dichtergeist.	On the outer side of the last; divided into two halves by the coronal suture.
24. *Goodness; benevolence; mildness; compassion; sensibility; moral sense; conscience; bonhommie.* (*G.*) Gutmüthigkeit, Mitleiden, moralischer Sinn, Gewissen.	Indicated by an oblong prominence above the organ of comparative sagacity; almost at the frontal suture.
25. *Imitation; mimicry.* (*G.*) Nachahmungssinn.	At the outer side of the last.
26. *God and religion; theosophy.* (*G.*) Theosophisches Sinn.	At the top of the frontal bone and at the superior angles of the parietal bones.
27. *Firmness; constancy; perseverance; obstinacy.* (*G.*) Stetigkeit, fester Sinn.	The top of the head; at the anterior and most elevated part of the parietal bones.

The first nineteen of those, according to Gall, are common to man and animals: the remaining eight, man possesses exclusively. They are, consequently, the attributes of humanity.

Dr. Spurzheim,[1] a fellow-labourer with Gall, who accompanied him in his travels, and was associated with him in many of his publications, added other faculties, so as to make the whole number thirty-five; but they were not embraced by Gall; indeed, several of the positions of Spurzheim are repudiated by Gall's followers.[2] The organs admitted by Spurzheim are given on the next page: the numbers correspond with those of the illustrations.

On the situation of the different encephalic organs, Gall remarks,—1st. That those which are common to man and animals are seated in parts of the encephalon common to both:—at the posterior, inferior, and anterior inferior, portions. On the contrary, those, that are exclusive to man, are situate in parts of the encephalon that exist only in him;—in the anterior superior parts, which form the forehead. 2dly. The more indispensable a faculty, and the more important to the animal economy, the nearer is its organ to the median line, and to the base of the encephalon. 3dly, and lastly. The organs of the faculties, that aid, or are similar to each other, are generally situate in proximity.

In his exposition of each of these organs, and of the reasons that induce him to assign it as the seat of a special faculty, he sets out by demonstrating the necessity of the faculty, which he regards as fundamental and primary, and to which he assigns a special nervous system or organ in the encephalon. 2dly. He endeavours to show, that this

[1] Phrenology, Amer. edit., Boston, 1833.
[2] Elliotson, Human Physiology, p. 384, and 1147, London, 1840.

faculty is really primary. He considers it to be such, whenever psychical facts show, that it has its exclusive source in organization; for

Fig. 141.

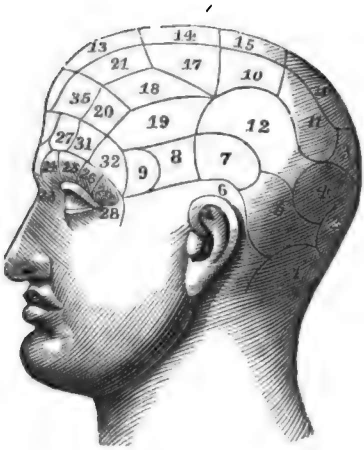


Fig. 142.

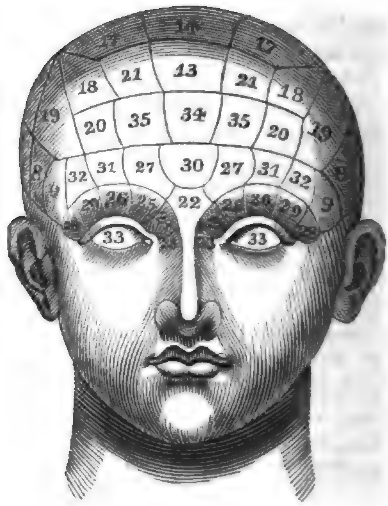
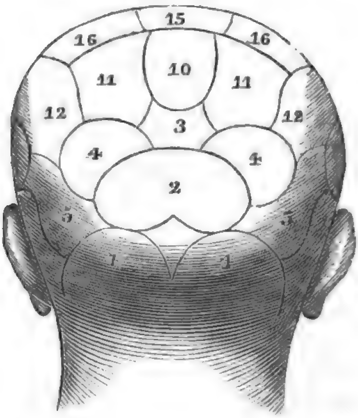


Fig. 143.



Phrenological Organs according to Spurzheim.

1. Amativeness. 2. Philoprogenitiveness. 3. Inhabitiveness. 4. Adhesiveness or Attachment. 5. Combativeness. 6. Destructiveness. 7. Constructiveness. 8. Acquisitiveness. 9. Secretiveness. 10. Self-esteem. 11. Love of Approbation. 12. Cautiousness. 13. Benevolence. 14. Veneration. 15. Firmness. 16. Conscientiousness or Justice. 17. Hope. 18. Marvellousness. 19. Wit. 20. Ideality. 21. Imitation. 22. Individuality. 23. Form. 24. Size. 25. Weight and Resistance. 26. Colour. 27. Locality. 28. Numeration. 29. Order. 30. Eventuality. 31. Time. 32. Melody or Tune. 33. Language. 34. Comparison. 35. Causality.

example, when it is not common to all animals and sexes; when, in the one possessing it, it does not exhibit itself in a ratio with the other faculties; has its distinct periods of developement and decrease; and does not, in this respect, coincide with the other faculties; when it can

be exerted, be diseased, and continue sound alone, or be transmitted alone from parent to child, &c. Lastly, he points out the part of the encephalon, which he considers to be its organ, founding his decision on numerous empirical observations of the encephalon of men and animals, that have possessed, or been devoid of, the faculty and organ in question; or have had them in unequal degrees of developement.

It is impossible, in a work of this kind, to exhibit all the views of Gall, and the arguments he has adduced in favour of the existence of his twenty-seven faculties. The selection of one—the *instinct of generation*—will be sufficient to show how he treats of the whole. Gall's *instinct of generation* is that, which, in each animal species, attracts the individuals of different sexes towards each other for the purpose of effecting the work of reproduction. The *necessity* for such an impulse for the general preservation of animals is manifest. It is to the continuance of the species what the sensation of hunger is to that of the individual. Again: it is certainly *primary* and *fundamental*, for it is independent of all external influence. It does not make its appearance until puberty, and disappears long before other faculties. In many animals it returns periodically. In each animal species, and in each individual, it has a special and different degree of energy; although external circumstances may be much the same in all, or at least may not present differences in any manner proportionate to those of the instinct. It may be either alone active, amidst the languor of other faculties; or may be alone languishing. Lastly, it cannot be referred to the genital organs, for it has been observed in children, whose organs have not been developed: it has frequently continued to be felt in eunuchs; and has been experienced by females who, owing to original monstrosity, have had neither ovary [?] nor uterus. The part of the encephalon which is the *organ* of the instinct, is, according to Gall, the *cerebellum*. His reasons for this belief are the following. 1st. In the series of animals, a cerebellum exists only in those which are reproduced by copulation, and which, consequently, must have the instinct in question. 2dly. There is a perfect coincidence between the periods at which the cerebellum becomes developed, and the appetite appears. In infancy, it does not exist; and the organ is therefore small. 3dly. In every species of animal and in every individual, there is a ratio between the size of the cerebellum and the energy of the inclination. In males, in whom it is generally more imperious, the cerebellum is larger. 4thly. A ratio exists between the structure of the cerebellum and the kind of generation. In oviparous animals, for instance, the cerebellum is smaller at its median part; and it is only in the viviparous, that hemispheres exist. 5thly. A similar ratio obtains between the cerebellum and external genital organs. If the latter are extirpated at an early age, the developement of the cerebellum is arrested, and it continues small for the remainder of life. Neighbouring parts, which are attributes of the male sex, as the horns of the stag, and the crest of the cock, are often similarly stunted. On the other hand, the cerebellum, in its turn, exerts an intimate influence on the venereal appetite; and modifies the external genital organs. Injuries of the cerebellum either render the person impotent, or excite erotic mania. In nymphomania, the patient often

complains of acute pain in the nape of the neck; and this part is more tumid and hot in animals at the rutting season. Gall asserts, that he had noticed in birds, that the cerebellum is not the same in size and excitement during the season of love as at other times; and he affirms, that if erection be observed in those who are hanged, or in consequence of the application of a blister or a seton to the nape of the neck, or of the use of opium, or in such as are threatened with apoplexy, especially when the apoplexy is cerebellous,[1] or during sleep, the effect is, in all these cases, owing to congestion of blood in the brain in general, and in the cerebellum in particular. From these data, Gall concludes, that the cerebellum is the organ of the instinct of reproduction; and he remarks, that as this organ presides over one of the most important faculties, it is situate on the median line; and at the base of the skull. In this manner, he proceeds, with more or less success, in his investigation of the other cerebral organs and faculties.

But Gall does not restrict himself to the physiological applications of his system. He endeavours to explain the differences that exist between him and other philosophers. He rejects the primary faculties of *instinct*, *intelligence*, *will*, *liberty*, *reason*, *perception*, *memory*, *judgment*, &c., of the metaphysician, as mere generalizations of the mind, or common attributes of the true primary faculties. Whilst, in the study of physics, the general and special qualities of matter have been carefully distinguished, and the latter have been regarded as alone deciding the particular nature of bodies, the metaphysician, says Gall, has restricted himself to general qualities. For example, it is asserted, that "to *think* is to *feel*." Thought is, doubtless, a phenomenon of sensibility; but it is a sensitive act of a certain kind. To adhere rigidly to this expression, says Gall, is but to express a generality, which leaves us in as much ignorance as to what thought is, as we should be of a quadruped or bird, by saying that it is an animal; and as, to become acquainted with such animals, their qualities must be specified, so to understand thought, the kind of sensation that constitutes it must be specified. *Instinct*, according to him, is a general expression, denoting every kind of internal impulse; and, consequently, there must be as many instincts as there are fundamental faculties. *Intelligence* is likewise a general expression, designating the faculty of knowledge; and as there are many instincts, so there are many kinds of intelligence. Philosophers, he thinks, have erroneously ascribed instinct to animals, and intelligence to man. All animals have, to a certain extent, intelligence; and in man many faculties are instincts. Neither is the *will* a fundamental faculty. It is only a judgment formed amongst several motives, and the result of the concourse of actions of several faculties. There are as many desires as faculties; but there is only one will, which is the product of the simultaneous action of the intellectual forces. So that the will is frequently in op-

[1] A case of Arachnitis Cerebelli—in which there was genital excitement—is reported by the author, in Lond. Med. Rep. for Oct., 1822. For cases of cerebellous disease, without genital excitement, see Duplay, in Archives Générales de Médecine, Nov., 1836; Müller's Elements of Physiology, by Baly, 1st edit. p. 833, Lond., 1838; and Longet, Anat. et Physiol. du Système Nerveux, tom. i. Paris, 1842; and Traité de Physiologie, ii. 267, Paris, 1850.

position to the desires. The same may be said of *liberty* and *reason;* to the former applies what has been remarked of the will, and the latter is only the judgment formed by the superior intellectual faculties. In this respect, however, he remarks, it must not be confounded with intelligence : many animals are intelligent, but man alone is rational.

On the other hand, what are termed, in the intellect, *perception*, *memory*, *judgment*, *imagination*, &c., are attributes common to all the intellectual faculties; and cannot, consequently, be considered primary faculties. Each faculty has its perception, memory, judgment, and imagination; and, therefore, there are as many kinds of perception, memory, judgment, and imagination, as there are primary intellectual faculties. This is so true, says Gall, that we may have the memory and the judgment perfect upon one point, and totally defective upon another. The memory of musical tones, for instance, is not the same as that of language; and he who possesses the one may not have the other. The imaginations, again, of the poet, musician, and philosopher, differ essentially from each other. These faculties are, therefore, according to him, nothing more than different modes of the activity of all the faculties. Each faculty perceives the notion to which it has been attracted, or has *perception;* each preserves and renews the recollection of this notion, or has *memory*. All are disposed to act without being excited to action from without, when the organs are largely developed, or have considerable intrinsic activity: this gives rise to *imagination;* and, lastly, every faculty exerts its function with more or less perfection, whence results *judgment*. *Attention*, in his view, is only the active mode of exercise of the fundamental faculties of the intellect; and being an attribute of all, it cannot be called a primary faculty.

As regards the *affective faculties*, or what have been called the *passions* and *affections*, Gall, in the first place, asserts, that the term *passion* is faulty when used to indicate a primary faculty. It ought only to designate the highest degree of activity of any faculty. Every faculty requires to be put into action, and according to the degree of activity which it possesses, it is a *desire*, a *taste*, an *inclination*, a *want*, or a *passion*. If it be only of the medium energy, it is a *taste:* if extremely active, a *passion*. There may, consequently, be as many passions as there are faculties. We speak of a *passion for study*, or a *passion for music*, as we do of the *passion of love*, or of *ambition*. Gall objects, also, to the word *affection*, which, according to him, expresses only the modifications presented by the primary faculties, according to the mode in which external and internal influences affect them. Some of these are common to all the faculties, as those of *pleasure* and *pain*. Every faculty may be the occasion of one or the other. Other affections are special to certain faculties; as *pretension*, which, he says, is an affection of *pride*, and *repentance* an affection of the moral sense. Finally, affections are *simple* or *compound: simple* when they only bear upon one faculty, as *anger*, which is a simple affection of the faculty of self-defence;—*compound*, when several faculties are concerned at the same time, as *shame*, which is an affection of the primary faculties of the *moral sense* and *vanity*.

Gall reproaches the moralists with having multiplied too much the number of primary affective faculties:—in his view, the modifications of a single faculty, and the combination of several, give rise to many sentiments, that are apparently different. For instance, the primary faculty of *vanity* begets *coquetry*, *emulation*, and *love of glory*. That of *self-defence* gives rise to *temerity*, *courage*, a *quarreling spirit*, and *fear*. *Contempt* is the product of a combination of the faculties of *pride* and the *moral sense*, &c.

Lastly; as regards their psychical differences, Gall divides all men into five classes. *First.* Those in whom all the faculties of humanity predominate; and in whom, consequently, organization renders the developement of the mind and the practice of virtue easy. *Secondly.* Those in whom the organs of the animal faculties predominate; and who, being less disposed to goodness, need the aid of education and legislation. *Thirdly.* Those in whom all the faculties are equally energetic, and who may be either worthy, or great criminals, according to the direction they take. *Fourthly.* Those who, with the rest of the faculties nearly equal and mediocre, may have one predominant. *Fifthly*, and *lastly.* Those who have the faculties alike mediocre:—which is the most numerous class. It is rare, however, he remarks, that the characters and actions of men proceed from a single faculty. Most commonly, they are dependent upon the combination of several; and, as the possible combinations of so many faculties are almost innumerable, the psychical varieties of mankind must be extremely various. Again, as each of the many organs of the brain may have, in different men, a particular degree of developement and activity, seeing that each of the faculties, which are their products, has most commonly a particular shade in every individual; as these organs can establish between each other a great number of combinations; and as men, independently of the differences in their cerebral organization, which give rise to their *dispositions*, never cultivate and exert their faculties in an equal and similar manner, it may be conceived, that nothing ought to be more variable than the intellectual and moral characters of men; and we may thus explain, why there are no two men alike in this respect.

Such is a general sketch of the physiological doctrine of Gall, which we may sum up in the language of the author, in his *Revue Sommaire*, appended to his great work. "I have established, by a considerable number of proofs, as well negative as positive, and by the refutation of the most important objections, that the encephalon alone has the immense advantages of being the organ of the mind. Farther researches on the measure of the degree of intelligence of man and animals have shown, that the encephala are more simple or more complex, as their instincts, desires, and faculties are more simple or more compound; that the different regions of the encephalon are concerned in different categories of function; and, finally, that the encephalon of every species of animal, and, consequently, that of man, constitutes an aggregation of as many special organs, as there are essentially different moral qualities and intellectual faculties in the man or

animal. The moral and intellectual dispositions are innate. Their manifestation is dependent upon organization. The encephalon is the exclusive organ of the mind. Such are four incontestable principles, forming the whole physiology of the encephalon;"—and he adds;—"the detailed developement of the physiology of the encephalon has unveiled the deficiencies of the hypotheses of philosophers regarding the moral and intellectual powers of man; and has been the means of bringing to light a philosophy of man, founded on his organization, and, consequently, the only one in harmony with nature."[1]

It is impossible to enter, at length, into the various facts and hypotheses developed in the preceding exposition. The great points of doctrine in the system of Gall, are:—*First.* That the encephalon consists of a plurality of organs, each engaged in a separate, distinct office,—the production of a special intellectual or moral faculty. *Secondly.* That each of these organs ends at the periphery of the encephalon; and is indicated by more or less developement of the part; and *Thirdly.* That, by observation of the skull, we may be enabled to detect the protuberance, produced by such encephalic developement; and thus indicate the seat of the encephalic organs of the different faculties. It has been shown, in the preceding history, that the notion of the plurality of organs has prevailed extensively in all ages; and whatever may be the merit of the arguments adduced by Gall on this subject, it is difficult not to conceive, that different primary faculties may have their corresponding organs. Simple inspection of the encephalon indicates that it consists of numerous parts, differing essentially in structure and appearance from each other; and it is but philosophical to presume, that these are adapted to equally different functions, although our acquaintance with the physiology of the organs may not be sufficiently extensive to enable us to designate them. Of the innate character of several of the faculties described by Gall, it is scarcely possible for us to admit a doubt. Take, for instance, the *instincts of generation* and of *love of progeny.* Without the existence of these, every animal species would soon be extinct. It seems fair, then, to presume, that these instincts or innate faculties may have encephalic organs specially concerned in their manifestation. Gall places them in the posterior part of the head,—the instinct of generation in the cerebellum; and his causes for so doing have been cited; yet, striking as his statement in regard to the encephalic seat of the instinct of generation seems to be, it has been contested by many physiologists,—by MM. Broussais, Foville, and Pinel-Grandchamp, Rolando, Flourens, Desmoulins, Calmeil, and others; and, not only by argument, but by that which must be the test of the validity of the doctrines of the phrenologists—direct experiment. It has been shown, indeed, that the genital excitement which is supposed by the followers of Gall to be seated in the cerebellum, can be equally produced by irritating the posterior column of the spinal marrow; and it would seem, that coincidence of disease of the spinal cord with affection of the genital organs is much more frequent.[2] Ac-

[1] Sur les Fonctions du Cerveau, vi. 500, Paris, 1825.
[2] Müller's Elements of Physiology, by Baly, p. 833, Lond., 1838.

cording to Burdach, the proportion of cases of disease of the cerebellum, in which there is any manifest affection of the sexual organs, is really very small,—not above one in seventeen. The results, too, of unprejudiced observation, as to the comparative size of the cerebellum in different animals, are by no means favourable to the phrenological doctrine. There are many highly salacious animals—as the kangaroo, and the monkey—which are not distinguished for unusual size of cerebellum. A strong argument, as before observed, in favour of this function of the cerebellum, is founded on the assertion, over and over again repeated, that in animals that have been castrated young, it is much smaller than in the entire male; but the results of the experiments of M. Lassaigne, suggested by M. Leuret,[1] are directly opposed to this. These were made on ten stallions, of the ages of from nine to seventeen years; on twelve mares, aged from seven to sixteen years; and on twenty-one geldings, aged from seven to seventeen years. The weight of the cerebrum, estimating the cerebellum as 1, was thus expressed.

	Average.	Highest.	Lowest.
Stallions	7·07	7·46	6·25
Mares	6·59	7·00	5·09
Geldings	5·97	7·44	5·16

The average proportional size of the cerebellum in geldings was therefore positively greater than in entire horses and mares. It was also found to be absolutely heavier in the following proportions.

	Average.	Highest.	Lowest.
Stallions	61	65	56
Mares	61	66	58
Geldings	70	76	64

It would seem, that the dimensions of the cerebrum are usually reduced by castration; as in the following table.

	Average.	Greatest.	Least.
Stallions	433	485	350
Mares	402	432	336
Geldings	419	566	346

These observations are certainly entirely opposed to the statements of the phrenologists; and are more favourable to the idea of the cerebellum being connected with muscular power. Geldings, as is well known, are employed in active labour; whilst stallions are rarely called upon to exert much effort, being kept especially to propagate their kind. The views, however, regarding the influence of the cerebellum, some of which have an essential bearing on this question, will be given under the head of MUSCULAR MOTION. It will be obvious, moreover, that if a single case of absence of the cerebellum should be observed in which erotic desires exist; it would be fatal to the views of the phrenologist. Such cases are rare, but one has been witnessed and recorded by M. Combette,[2] and no doubt can exist as to its authenticity. On examining the encephalon of a young girl, who had been addicted to masturbation, a gelatiniform membrane of a semicircular shape, united to the

[1] Anat. Compar. du Système Nerveux, tom. i. p. 427.

[2] Revue Médicale, ii. 57, Paris, 1831; Cruveilhier, Anat. Pathol., livr. xv. pl. v.; and Longet Anat. et Physiol. du Système Nerveux, i. 755, Paris, 1842; and Traité de Physiologiè, ii. 270, Paris, 1850.

medulla oblongata by two membranous and gelatinous peduncles, was observed in place of the cerebellum. The one on the right side had been torn. Near these peduncles, M. Combette found two small masses of white substance, isolated and detached, as it were, of the size of a pea. It is not, therefore, a matter of astonishment, that from an examination of all the evidence adduced on this matter, M. Longet[1] should have concluded, that neither pathology, morbid anatomy, comparative anatomy nor experimental physiology leads to the admission of the views of the phrenologist in regard to the functions of the cerebellum.

In regard, too, to the cerebral seat of the love of progeny—philoprogenitiveness, as it is termed—it is a fatal objection, that, although the instinct is strongly developed in the lower animals, the posterior lobes recede as we descend in the scale from man, and ultimately leave the cerebellum uncovered.

One of the greatest objections brought against the system of Gall is the independence of the different faculties of each other. Each is made to form a separate and independent state, with no federative jurisdiction to produce harmony in their actions, or to regulate the numerous independent movements and complicated associations, which must inevitably occur in the various intellectual and moral operations. Gall appears indeed to have lost sight of the important doctrine of association, which applies not only to the ideas, but to every function of the frame; and with which it is so important for the pathologist particularly to be acquainted.

The second point of doctrine,—that each of the cerebral organs ends at the periphery of the encephalon, and is indicated by more or less developement of the part,—is attended with equal difficulties. It is admitted, as we have seen, by the most eminent physiologists, that the exterior of the brain is probably chiefly concerned in the mental and moral manifestations. Almost all believe, that this function is restricted to the brain proper. Gall and his followers include the cerebellum. Yet we meet with cases, which appear to militate strongly against this notion. Hernia of the brain is one: in this affection, owing to a wound of the cranium and dura mater, a portion of the cerebral substance may protrude and be removed; yet the individual may, to all appearance, retain his faculties unimpaired. This is explained by the craniologist, by presuming, that as the fibres of the brain are vertical, their extremities alone have been removed, a sufficient amount of fibres remaining for the execution of the function; and he farther entrenches himself in the difficulty of observing accurately, whether the faculties be really in their pristine integrity. He asserts, that it is frequently difficult to prove the existence of mental aberration; that the precise line of demarcation between reason and unsoundness of mind is not easily fixed; and that commonly, in these cases, attention is paid only to the most general qualities; and if the patient be seen to take food and medicine when offered, to reply to questions put to him, and to have consciousness, the moral sense is esteemed to be free, and in a state of

[1] Op. cit., p. 272.

integrity. It must, however, be admitted, that the explanation of the craniologist on these topics is feeble and unsatisfactory. It is gratuitously assuming, that observation in such cases has been insufficient; and if he finds, that the fact in question militates against the faith he has embraced, he is too apt to deny its authenticity altogether. With all the candour which Gall possessed, this failing is too perceptible in his writings.

In many of the cases of severe injury of the brain on record, but one hemisphere was implicated; and, accordingly, the impunity of the intellectual and moral manifestations has been ascribed to the cerebrum being a double organ; so that, although one hemisphere may have been injured,—the other, containing similar organs, may be capable of carrying on the function; as one eye can still execute vision, when the other is diseased or lost. Cases, however, have occurred in which the faculty was lost, when only one hemisphere was implicated. One interesting example, the author heard Mr. Combe relate. A gentleman suddenly forgot all words but *yes* and *no;* and after death a lesion was found in the left hemisphere of the brain, involving the phrenological organ of language. The explanation by Mr. Combe of this phenomenon is plausible, but not probable. It appears to me, he observed, "that the lesion's being on one side only accounts for his power of understanding words, while he had not the power of employing them."[1] Many cases, again, are recorded, in which injury was sustained by both hemispheres, and in corresponding parts, yet the faculties persisted;[2] whence Müller has concluded, that the histories of injuries of the head are directly opposed to the existence of special regions of the brain, destined for special mental faculties. An interesting case of this nature was reported to the Royal Academy of Sciences of Paris, by M. Blaquière of Mexico.[3] A child, playing with a loaded pistol, discharged it accidentally. The ball struck his younger brother, four years and a half old; entered at one temporal region, and came out at the other. For twenty-six days after the accident, the child apparently possessed all its intellectual faculties. Memory and judgment did not seem to be in the slightest degree impaired: the boy was as gay as usual; had appetite, and slept pretty well. The wounds were both situate about an inch and a half below the external commissures of the eyes. On the 26th day, symptoms of cerebral inflammation supervened, and the

[1] Combe's Lectures, by Boardman, p. 261, New York.

[2] For many such cases, see Longet, Anatomie et Physiologie du Système Nerveux, i. 670, Paris, 1842; and a remarkable one by Mr Ford, and another by Dr. Cowan, copied into the Amer. Journ. of the Med. Sciences, Jan., 1846. See, also, a fatal case of disorganization of the brain, without corresponding derangement of the intellectual and moral acts, by Dr. G. W. Boerstler, of Lancaster, Ohio, in Dunglison's American Medical Intelligencer, No. 1, for April 1, 1837. Mr. Combe, in his work,—"*Notes on the United States of North America, during a phrenological visit in* 1838–39–40;" Phila., 1841—refers to a case of injury of both hemispheres, which, he thinks, from examining the case, was confined almost entirely to the organs of Eventuality. The man recovered, and was exhibited to Mr. Combe with a history of his case by Drs. Knight and Hooker, of New Haven. In the opinion of the latter, the intellectual faculties were not impaired.—Vol. ii. p. 276. See, also, connected with this subject, Dr. A. L. Wigan, The Duality of the Mind proved by the Structure, Functions, and Diseases of the Brain, &c., Lond., 1844.

[3] Comptes Rendus, 23d Sept., 1844.

boy died on the 29th. On examination after death, the anterior and superior regions of both hemispheres were found to have been traversed by the ball. The ventricles were untouched. Throughout the whole track of the ball suppuration existed. The meninges were inflamed. M. Blaquière considers the case to be fatal to phrenological doctrines, as the seats of several important phrenological faculties were destroyed, and yet no functional affection of the brain was discovered. Cases of hydrocephalic patients are likewise cited, who have preserved their faculties entire. These Gall[1] explains, by affirming, that the brain is not dissolved in the fluid of the dropsy; that it is only deployed, and distended by the presence of the fluid; and as the distension takes place slowly, and the pressure is moderate, the organ may be so habituated to it as to be able to continue its functions. Lastly, some experiments of Duverney[2] have been adduced as objections to the view of Gall. These consisted in removing the whole of the brains of pigeons; yet no change seemed to be produced in their faculties; but, in reply to this, it is asserted, that Duverney could only have removed some of the superficial parts of the organ; for, whenever the experiment has been repeated so as to implicate the deeper-seated portions, opposite results have been obtained.

The truth is, that under any view of the subject these facts are equally mysterious. We cannot understand why, in particular cases, such serious effects should result from severe injury of the encephalon; and, in others, the comparative immunity attendant upon injury to all appearance equally grave. Pressure, of whatever nature, seems to be more detrimental than any other variety of mechanical mischief; and it is not uncommon for us to observe a total privation of all mental and moral acts, by the sudden effusion of blood, of no greater magnitude than that of a pea, into the substance of the brain; whilst a gun-shot wound, that may occasion the loss of several tea-spoonfuls of brain, or a puncture of the organ by a pointed instrument, may be entirely consistent with the presence of perfect consciousness.

The doctrine, that by observation of the skull we may be able to detect the protuberances produced by the encephalic organs of the different faculties, has, as we have seen, laid the foundation for the whole system of craniology, with all the extensions given to it by absurdity and vain enthusiasm. It has been before remarked, that the size of an organ is but one of the elements of its activity; that by cranioscopy we can of course judge of this element only; and it need scarcely be said, that myriads of observations would be necessary before we could arrive at any accurate specification of the seats of the encephalic faculties, even were we to grant, that separate organs can be detected by the mode of examination proposed by the cranioscopists. Gall asserts, that the whole "physiology of the encephalon is founded on observations, experiments, and researches a thousand and a thousand times repeated on man and animals;" yet the topographical division of the skull proposed by him can hardly be regarded otherwise than premature, to

[1] Op. citat., ii. 263.
[2] Adelon, Physiologie de l'Homme, 2de édit., i. 502, Paris, 1829.

say the least of it;[1] and the remark applies *à fortiori* to that of Spurzheim.

It is, indeed, difficult to grant, that the same convolutions can be the encephalic organs of distinct faculties; and if the views now adopted by many of the phrenologists, be admitted, that the number and size of the convolutions and the depth of the anfractuosities be any index of the developement of an organ; it is obviously impossible by an examination of the skull to form the slightest judgment on these points. Messrs. Leuret and Carpenter[2] are of opinion, that comparative anatomy and psychology—which have been so much invoked—when their evidence is fairly weighed, are very far from supporting the system. M. Flourens[3] and Retzius[4] have opposed it on anatomical, physiological, and psychological grounds; and Müller[5] thinks Magendie right in placing cranioscopy in the same category with astrology and alchemy. The author would not go so far; but he must candidly admit, that year after year's observation and reflection render him less and less disposed to consider, that even the fundamental points of the doctrine are founded on a just appreciation of the encephalic functions.

It is the mapping of the skull, accompanied by the self-conceit and quackery of many of the *soi-disant* phrenologists or craniologists, that has excited the ridicule of those who are opposed to the doctrine of innate faculties, and to the investigation of points connected with the philosophy of the human mind in any other mode than that to which they have been accustomed. Were we, indeed, to concede, that the fundamental principles of craniology are accurate, we might hesitate in adopting the details; and still more in giving any weight to it as a practical science. Gall and Spurzheim would rarely venture to pronounce on the psychical aptitudes of individuals from an examination of their skulls; and when they did, they frequently failed. "When Gall," says Dr. Burrows,[6] "was in England, he went in company with Dr. H. to visit the studio of the eminent sculptor, Chantry. Mr. C. being at the moment engaged, they amused themselves in viewing the various efforts of his skill. Dr. Gall was requested to say, from the organs exhibited in a certain bust, what was the predominant propensity or faculty of the individual. He pronounced the original must be a great poet. His attention was directed to a second bust. He declared the latter to be that of a great mathematician: the first was the bust of Troughton, and the second that of Sir Walter Scott!"

This kind of hasty judgment from manifestly inadequate data is the every-day practice of the itinerant phrenologist, whose oracular dicta too often draw ridicule not only on the empiric himself, but on a system which is worthy of a better fate. Ridicule is the harmless but

[1] Müller's Elements of Physiology by Baly, p. 837, Lond., 1838.

[2] Human Physiology, p. 226, Lond., 1842.

[3] Journal des Savans, Nov., 1841, & Févr. & Avril, 1842; and Phrenology Examined, translated from the second edition of 1845, by Professor Meigs, Philad., 1846.

[4] Beurtheilung der Phrenologie vom Standpunkte der Anatomie aus., Müller's Archiv., Heft 3, s. 233, Berlin, 1848.

[5] Op. citat., p. 837.

[6] Commentaries on the Causes, Forms, Symptoms, and Treatment of Insanity, Lond., 1828.

attractive weapon, which has usually been wielded against it; and too often by those who have been ignorant both of its principles and details. It is not above twenty years since one of the most illustrious poets of Great Britain included in his satire the stability of the cow-pox, galvanism, and gas, along with that of the metallic tractors of Perkins—

> "The cow-pox, tractors, galvanism, and gas,
> In turns appear to make the vulgar stare
> Till the swoll'n bubble bursts, and all is air."
> BYRON'S "*English Bards and Scotch Reviewers.*"

Yet, how secure in its operation, how unrivalled in its results, has vaccination every where exhibited itself!

Indiscriminate divination from measurement of heads has been a sad detriment to phrenology as a branch of physiological science; and has been grievously deplored by enlightened phrenologists. "Highly as we estimate the discovery of Gall,"—says one of the ablest of these[1]—"immense as we regard the advantages which may be ultimately derived from phrenology, we confess that we wish to see it *less* regarded, studied, and pursued as a separate science, and *more* as a branch of general physiology;" and he adds: "In reviewing the circumstances which have tended to lower phrenology in the estimation of scientific men, and, consequently, to retard both its progress as a science, and the general recognition of its leading truths, we should but very imperfectly perform our task, if we did not refer, in the strongest possible terms of reproof and condemnation, to the too prevalent proceeding of examining living heads in minute detail and indiscriminately, and supplying the owners with an account of the 'developement,' often on the receipt of a fee, varying in amount, as there is furnished or omitted a general deduction as to the character and probable conduct of the individual, with or without the 'philosophy,' according to the phraseology of practitioners of this art. We unhesitatingly maintain, that the science is not sufficiently advanced to supply evidence of its truth from every head, or from any one head, and consequently, that such practice, as a general one, is so much pure charlatanism. Where any strongly marked peculiarity of individual character exists, its outward sign, in appropriate subjects, will certainly be detected; but, from the very nature of the thing, these cases must constitute not the rule, but the exception. The practice we condemn, however, makes no distinction of instances. Injudicious zeal, the common ally of ignorance, a wish for effect, not unfrequently more sordid motives, stimulate the self-styled phrenologist in this empirical career; and, as a matter of course, the errors and mistakes perpetually made are constantly appealed to as indicative of the sandy foundations of the entire phrenological edifice. We write advisedly in this our unqualified reprobation of the popular custom of 'taking developements.' We believe it to be an extension of the practical application of phrenology much beyond its legitimate bounds; and we appeal to any one having acquaintance with its results, whether any thing like uniformity—the true test of accuracy—is obtained in the majority of cases, even when the most experienced and

[1] British and Foreign Medical Review, July, 1842.

dexterous pronounce their judgment, if their explorations be conducted separately. We ourselves have even witnessed the greatest possible discrepancies. Nay, we have seen the *same* phrenologists furnish one character from the head, and a totally different one from the cast, whilst in ignorance of the original of this latter. This we have known to happen, not merely in the practice of one of your shilling-a-head itinerants, but in that of one not unknown to fame in the annals of the science." Such are the views of one, who, unlike the author, expects much from phrenology; and has done much to give it countenance. Yet men will still form their judgments in this manner; and a solitary coincidence, as in all analogous cases, will outweigh a dozen failures.[1]

The doctrine of Gall requires repeated unbiassed and careful experiments, which it is not easy for every one to institute; and this is one of the causes why the minds of individuals must long remain in doubt regarding the merits or demerits of the system. From mere metaphysicians, who have not attended to the organization and functions of the frame, especially of its encephalic portion, it has ever experienced the greatest hostility; although their conflicting views regarding the intellectual and moral faculties was one of the grounds for the division of the phrenologist. It is now, however, we believe, generally admitted by the liberal and scientific, that if we are to obtain a farther knowledge of the mental condition of man, it must be by a combination of sound psychological and physiological observation and deduction. It is time, indeed, that such a union should be effected, and that the undisguised and inveterate hostility, which exists between certain of the professors of these interesting departments of anthropology, should be abolished. "To fulfil, definitely, the object we had proposed to ourselves," says M. Broussais,[2] "we must infer from all the facts and reasoning comprised in this work,—1st. That the explanations of psychologists are romances, which teach us nothing new. 2dly. That they have no means of affording the explanations they promise. 3dly. That they are the dupes of the words they employ in disserting on incomprehensible things. 4thly. That the physiologist alone can speak authoritatively on the origin of our ideas and knowledge; and 5thly. That men, who are strangers to the science of animal organization, should confine themselves to the study of the instinctive and intellectual phenomena in their relations with the different social states of existence."

This is neither the language nor the spirit that ought to prevail among the promoters of knowledge.

Lastly.—Physiologists have inquired, whether there may not be some particular portion of the brain, which holds the rest in subservience; some part in which the mind exclusively resides;—for such was probably the meaning of the researches of the older physiologists into the seat of the soul. It is certain, that it is in the encephalon, but not in the whole of it; for the organ may be sliced away, to a

[1] See, on these subjects, the author's Medical Student, second edit., p. 256, Philadelphia, 1844.

[2] De l'Irritation et de la Folie, Paris, 1828; or Amer. edit. by Dr. T. Cooper, Columbia, S. C., 1831.

certain extent, with impunity. Gall, we have seen, does not admit any central part, which holds the others in subordination. He thinks, that each encephalic organ, in turn, directs the action of the others, according as it is, at the time, in a state of greater excitation. On the other hand, different physiologists admit of a central cerebral part, which they assert to be the seat of the ψυχη, *moi* or mind. They differ, however, regarding the precise situation of its domicile. At one time, the strange notion prevailed, that the seat of perception is not in the brain, but in its investing membranes. Des Cartes,[1] again, embraced the singular hypothesis, that the pineal gland is entitled to this pre-eminence. This gland is a small projection, seen in Fig. 9 (page 80), at the posterior part of the third ventricle; and, consequently, at the base of the brain. Being securely lodged, it was conjectured by that philosopher, that it must be inservient to some important purpose; and, upon little better grounds, he supposed, that the soul is resident there. The conjecture was considered to be confirmed by the circumstance, that, on examining the encephala of certain idiots, the gland was found to contain a quantity of sabulous matter. This was supposed to be an extraneous substance, which, owing to accident or disease, had lodged in the gland and impeded its functions; and the inference was drawn, that the part, in which such functions were impeded, was the seat of the soul. Nothing, however, is now better established than that the pineal gland of the adult always contains earthy matter.[2] Others, again, as Bontekoe,[3] La Peyronie,[4] and Louis, placed the mind in the corpus callosum; Vieussens in the centrum ovale; Digby[5] in the septum lucidum; Drelincourt[6] in the cerebellum; Ackermann in the Sinneshügel[7] (prominence or tubercle of the senses); Sömmering[8] in the fluid of the ventricles; and the greater part of physiologists in the point where the sensations are received and volition sets out,—the two functions, which, together, form the *sensorial power* of Dr. Wilson Philip.[9] Dr. Darwin[10] had previously employed this term in a more extended sense, as including the power of muscular contraction; but in Dr. Philip's acceptation, it is restricted to those physiological changes in which the mind is immediately concerned.[11]

The discrepancy among physiologists sufficiently demonstrates, that we have no positive knowledge on the subject.

[1] De Passion. Anim., Amst., 1664, and De Homine, p. 78, Lugd. Bat., 1664.

[2] Sömmering, De Lapillis vel prope vel intra Glandulam Pinealem sitis, Mogunt, 1785.

[3] Haller. Bibl. Anat., i. 673.

[4] Mém. de l'Académ. des Sciences, Paris, 1741.

[5] Of the Nature of Bodies and the Nature of Man's Soul, London, 1658.

[6] Opera. Anat., Lugd. Bat., 1684.

[7] This term he applies to the optic thalami and corpora striata; because, according to the then received opinion, the optic nerves originate in the optic thalami; and the olfactory nerves from the corpora striata.—Gall, Sur les Fonctions du Cerveau, ii. 57, Paris, 1825.

[8] De Corp. Human. Fabric., iv. § 98.

[9] An Experimental Inquiry into the Laws of the Vital Functions, p. 186, London, 1817.

[10] Zoonomia, 3d edit., ii. 103, Lond., 1801.

[11] Dr. W. Philip, ibid.; and especially his paper on the Powers of Life, in the Lond. Med. Gazette for March 18 and 25, 1837; also, his Treatise on Protracted Indigestion, &c., Amer. edit., Philad., 1843.

CHAPTER II.

MUSCULAR MOTION, ESPECIALLY LOCOMOTILITY OR VOLUNTARY MOTION.

The functions hitherto considered are preliminary to those that have now to attract attention. The former instruct us regarding the bodies that surround us; the latter enable us to act upon them; to execute all the partial movements, that are necessary for nutrition and reproduction; and to move about from place to place. All these last acts are of the same character; they are varieties of muscular contraction; so that sensibility and voluntary motion, or muscular contraction executed by the muscular system of animal life, comprise the whole of the life of relation. M. Magendie includes the voice and movements under the same head; but there is convenience in separating them; and in treating the functions of locomotility and expression distinctly, as has been done by M. Adelon.[1]

ANATOMY OF THE MOTORY APPARATUS.

The organs essentially concerned in this function are—the encephalon, spinal marrow, nerves, and muscles. The three first of these have been sufficiently described. The last, therefore, will alone engage us.

Muscles.

The muscles constitute the flesh of animals. They are distinguished by their peculiar structure and composition;—being formed of the elementary or primary fibrous tissue, already described. This tissue has the power of contracting, and thus of moving the parts into which it is inserted; hence, muscles have been termed *active* organs of locomotion, in contradistinction to bones, tendons, and ligaments, which are *passive*.

The elementary constituent of the whole muscular system is this primary, fibrous, or muscular tissue, the precise size and intimate texture of which have been the occasion of innumerable researches; and, as most of them have been of a microscopic character, they are highly discrepant, as a brief history will exhibit.

Leeuwenhoek[2] asserts, that some thousands of the ultimate filaments are required to form the smallest fibre visible to the naked eye. He describes these fibres as serpentine and cylindrical; and affirms, that they lie parallel to each other, and are of the same shape in all animals, but differ greatly in size. Their size, however, bears no proportion to that of the animal to which they belong. Muys[3] affirmed, that every apparent fibre is composed of three kinds of fibrils, each progressively

[1] Physiologie de l'Homme, 2de édit., ii. 1 & 204, Paris, 1829.
[2] Arcana Naturæ, p. 43.
[3] Investigatio fabricæ quæ in partibus musculos componentibus exstat, p. 274, Lugd. Bat., 1841.

smaller than the other; and that those of the medium size, although not larger than the ninth part of a very delicate hair, are composed of one hundred filaments. He supposed the ultimate filament to be always of the same size. Prochaska[1] says, that the ultimate fibre or filament is discernible, and that its thickness is about the $\frac{1}{80}$th part of the diameter of the red globules of the blood; and MM. Prévost and Dumas,[2] from the result of their microscopic observations, affirm, that 16,000 fibres may be contained in a cylindrical nerve, one millimeter or 0·039 of an inch, in diameter. The microscopic examinations of Mr. Skey,[3] which have been confirmed and developed by subsequent observers, led him to infer, that there is a distinction between the muscular fibres of animal and organic life; the former having, in man, an average diameter of $\frac{1}{400}$th of an inch. Each of these muscular fibres is divisible into bands or fibrillæ, and each of these is again subdivisible into about 100 tubular filaments, arranged parallel to each other: the diameter of each filament is $\frac{1}{18000}$th part of an inch, or about a third part of that of a blood-globule. The muscles of organic life he found to be composed, not of fibres similar to those described, but of filaments only; these filaments being interwoven, and forming a kind of untraceable net-work. The fibres of the heart appeared to possess a somewhat compound character of texture: the muscles of the pharynx exhibited the character of those of animal life, whilst those of the œsophagus, stomach, intestines, and arterial system possessed the character of those of organic

Fig. 144.

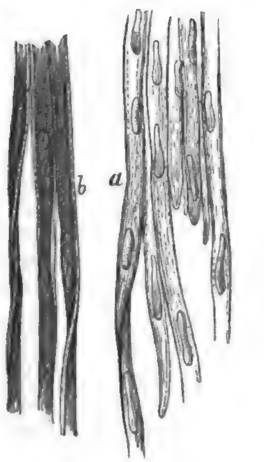
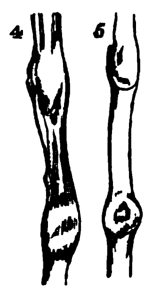


Fig. 145.



Non-striated Muscular Fibre.

At *b*, in its natural state. At *a*, showing the nuclei after the action of acetic acid.

4. A muscular fibre of organic life, with two of its nuclei; taken from the urinary bladder, and magnified 600 diameters. 5. Muscular fibre of organic life from the stomach, magnified the same.

life. He was unable to determine the exact nature of the muscular fibres of the iris. At the present day, muscular tissue is universally

[1] De Carne Musculari, p. 25, Vienn., 1778.
[2] Annales de Chimie, tom. xviii.; Magendie's Journal de Physiologie, tom. iii.
[3] Transactions of the Royal Society, for 1836.

divided into two kinds;—the one forming the *muscles of animal life*, the other the *muscles of organic life*. The former, called also *striated* and *striped muscles* (see Fig. 147), embrace all the voluntary muscles, as well as the heart, the muscular tissue of the pharynx and upper portion of the œsophagus: the latter, called also *non-striated* or *unstriped muscles*, constitute the proper contractile coats of the digestive tube from the middle of the œsophagus to the external sphincter ani, as well as those of the urinary bladder, trachea and bronchia, excretory ducts, gall bladder, vesiculæ seminales, pregnant uterus and Fallopian tubes; arteries, and—to a less degree—of the veins.

The intimate structure of the filaments has given rise to extraordinary contrariety of sentiment;—some, as Santorini, Heister, Cowper,[1] Vieussens, Mascagni,[2] Prochaska,[3] Borelli,[4] John Bernouilli, &c., believing them to be hollow; others, as Sir A. Carlisle,[5] and Fontana,[6] solid; some thinking them straight; others zigzag, spiral, or waved; some jointed; others knotted, &c. &c.[7] Borelli and J. Bernouilli announced, that each fibre consists of a series of hollow vesicles, filled with a kind of spongy substance or marrow;—the shape of the vesicles being, according to the former, rhomboidal,—according to the latter, spheroidal. Deidier conceived it to be a fasciculus, composed of an artery, vein, and lymphatic, enveloped by a nervous membrane, and held together by nervous filaments:—Prochaska, to consist of bloodvessels turned spirally around an axis of gelatinous or fibrinous substance, into the interior of which the blood rushed at the time of contraction. He says, that the visible fibres are not cylindrical, as they had been described by many observers, but of a polyhedral shape; and that they are generally flattened, or thicker in one direction than in the other. All are not of the same diameter: they differ in different animals, and in different parts of the same animal; and are smaller in young subjects. The filaments or ultimate fibres, which can only be seen with the microscope, have the same shape as the visible fibres: they are, however, always of the same magnitude. Sir A. Carlisle,[8]—whose opinions, on many subjects at least, are not entitled to much weight—describes the ultimate fibre as a solid cylinder, the covering of which is a reticular membrane, and the contained part a pulpy substance, regularly granulated, and of very little cohesive power when dead. The extreme branches of the bloodvessels and nerves, he says, are seen ramifying on the surface of the membrane enclosing the pulp, but cannot be traced into the substance of the fibre. Mr. Bauer[9] and MM. Prévost and Dumas[10] differed essentially from the observers already mentioned. Mr. Bauer found, that the muscular fibre was composed of a series of globules, arranged in straight lines; the size of the globule being $\frac{1}{2000}$th

[1] Myotomia Reformata, Lond., 1724.
[2] Prodromo, p. 97.
[3] Oper. Minor., P. i. 198.
[4] De Motu Animalium; addit. Johan. Bernouilli, M. D., Meditationes Mathematic. Musculorum, Lugd. Bat., 1710.
[5] Phil. Trans. for 1805, p. 6.
[6] Sur les Poisons, ii. 228.
[7] Elliotson's Physiology, p. 476.
[8] Op. citat.
[9] Sir E. Home, Lectures on Comp. Anat., v. 240, Lond., 1828.
[10] Appendix to Edwards, De l'Influence des Agens Physiques sur la Vie, Paris, 1824.

part of an inch in diameter; whilst M. Raspail[1] considers, that the intimate structure of the muscular tissue, when it is in its most simple state, consists of a bundle of cylinders, intimately agglutinated together, and disposed, in a very loose spiral form around the ideal axis of the group. These tubes are filled with a substance not wholly miscible with water, and may be regarded as elongated vesicles, united at each end to other vesicles of a similar character.

When a muscular fibre is seen through an ordinary microscope, it appears to be composed of longitudinal filaments, each consisting of a string of globules, about $\frac{1}{8000}$th of an inch in diameter. "But with a better instrument," says Mr. Mayo,[2] "such as that which Mr. Lister possesses, the delusion vanishes, and the parallel lines, which traverse the fibre, appear perfectly clean and even. Mr. Lister politely gave me an opportunity of examining this appearance, which was discovered by himself and Dr. Hodgkin."

Fig. 146.

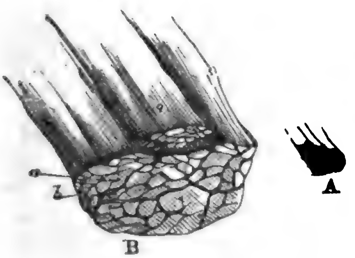
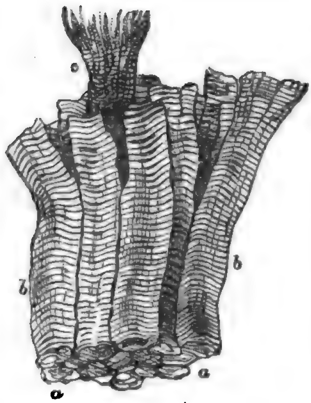


Fig. 147.



Striated Muscular Fibres.

Fig. 146.—A. A small portion of muscle, natural size. B. The same magnified 5 diameters, of larger and smaller fasciculi, seen in a transverse section.

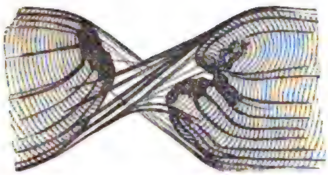
Fig. 147.—A few muscular fibres, being part of a small fasciculus, highly magnified, showing the transverse striæ. *a*. End view of *b b*, fibres; *c*. A fibre split into its fibrillæ.

The researches of Mr. Bowman[3] and others are as follows. When the smallest fibre, that can be seen by the naked eye, is examined by the microscope, it is found to consist of a number of cylindrical fibres lying parallel to each other, and closely bound together. These fibres present striæ—one set of which is longitudinal, the other transverse. When the fibres are separated from each other, and examined more closely, they may be resolved into fibrillæ, which, so far as at present known, are the ultimate elements of muscular structure. They are represented in Figure 153. The fibrillæ are bound together by

[1] Chimie Organique, &c., p. 211, Paris, 1833.
[2] Outlines of Human Physiology, chap. iii. 3d edit., London, 1833.
[3] Philosophical Transactions for 1840; art. Muscle, Cyclop. of Anat. and Physiol., Part xxiv., p. 507, July, 1842; and Todd and Bowman's Physiological Anatomy and Physiology of Man, Part i., Lond., 1843.

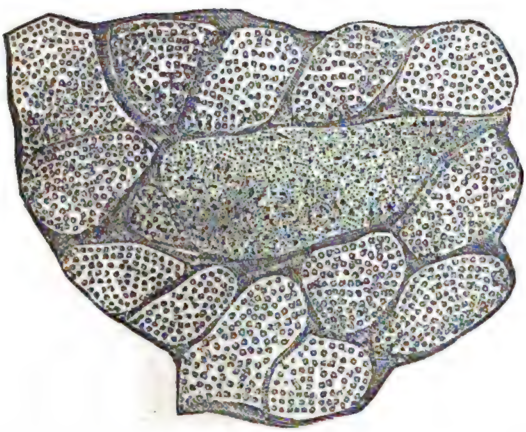
a delicate tubular sheath or *sarcolemma*, which may be distinctly seen, when the two ends of a fibre are drawn apart. The contained fibrillæ will rupture, whilst the sheath remains entire, as represented in Fig. 148. During the act of contraction, it is also sometimes observed to rise up in wrinkles, upon the surface of the fibre, as in Fig. 166. It is distinct from the cellular tissue that binds the fibres into fasciculi; does not appear to be perforated by nerves or capillary vessels; and evidently has no share in the contraction of the fibre. Although commonly described as cylindrical, these fibres would seem to be rather of a polygonal form, their sides being flattened against those of the adjoining fibres. Their size varies greatly in different classes of animals, and even in the same animal, and the same muscle. Mr. Bowman found them to be, in the human male, from $\frac{1}{307}$ to $\frac{1}{192}$ of an inch; in the female, from $\frac{1}{303}$ to $\frac{1}{384}$, and it has been estimated, that each fibre may be composed of from 500 to 800 fibrillæ. Illustration, Fig. 149, representing a transverse section of the fibres from the pectoral muscle of a teal; and Fig. 150, a transverse section of the ultimate fibres of the biceps, exhibit well the irregular shape and size, and the cut extremities of fibrils that go to the constitution of the fibre. Under the microscope each fibre exhibits a close alternation of light and dark lines crossing it transversely, which are presumed to be owing to the arrangement of beaded fibrillæ, as shown in Fig. 151. The beaded enlargements of the fibrillæ seem to adhere closely to each other, so that when the extremities of a fibre are drawn apart, it not unfrequently happens, that the disks formed by them separate.

Fig. 148.



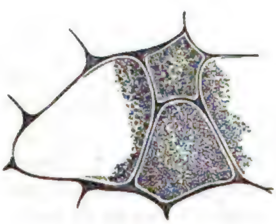
Fragments of an Elementary Fibre of the Skate, held together by the untorn but twisted Sarcolemma. (Todd & Bowman.)

Fig. 149.



Transverse Section of Fibres from the Pectoral Muscle of a Teal.

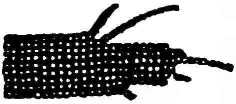
Fig. 150.



Transverse Section of Ultimate Fibres of Biceps. (Bowman.)

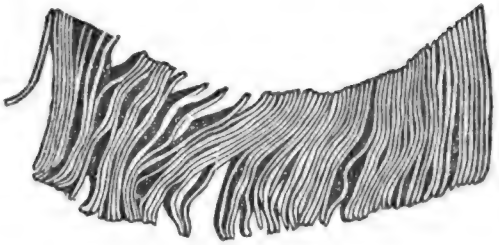
It has been affirmed, that the primitive component segments of the

Fig. 151.



Fragment of Muscular Fibre from macerated heart of Ox, showing formation of striæ by aggregation of beaded fibrillæ. (Bowman.)

Fig. 152.

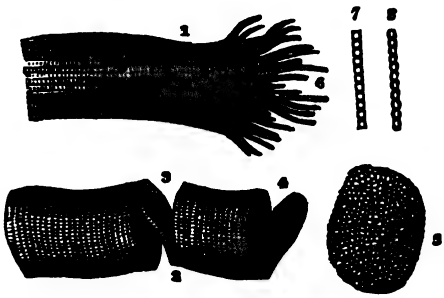


Portion of Human Muscular Fibre, separating into disks, by cleavage in direction of transverse striæ. (Bowman.)

fibrillæ are the ultimate elements of the fibre; these segments being connected longitudinally, so as to constitute the fibrillæ, the distinctness of which is marked, even in the complete fibre, by longitudinal striæ; whilst they also adhere laterally, so as to form disks, the partial separation of which gives origin to the transverse striæ.

The views of histologists on the whole of this subject have until recently been sufficiently discrepant. Dr. Martin Barry[1] revived a view of Döllinger, but which has met with little favour, and certainly needs demonstration, that the blood corpuscle is the immediate agent in the construction of many tissues, particularly the muscular, the elementary fibre of which—called by him *spiral fibre*—may even be detected in the nucleus of the corpuscle. Mr. Bowman[2] has affirmed, that the muscular fibre always presents, upon and within it, longitudinal dark lines, along which it will generally split up into fibrillæ, but it is by a fracture alone, that the fibrillæ are obtained. They do not exist as such in the fibre. He farther observed, that it occasionally happens that no disposition whatever is shown to this longitudinal *cleavage;* but

Fig. 153.



Fragments of Striated Elementary Fibres, showing a Cleavage in Opposite Directions.—Magnified 300 diameters.

1. Longitudinal cleavage. The longitudinal and transverse lines both seen. Some longitudinal lines darker and wider than the rest, and not continuous from end to end: this results from partial separation of the fibrillæ. 6. Fibrillæ, separated from one another by violence at the broken end of the fibre, and marked by transverse lines equal in width to those on the fibre. 7, 8 represent two appearances commonly presented by the separated single fibrillæ. (More highly magnified.) At 7, the borders and transverse lines are all perfectly rectilinear, and the included spaces perfectly rectangular. At 8, the borders are scalloped, the spaces bead-like. When most distinct and definite, the fibrilla presents the former of these appearances.—2. Transverse cleavage. The longitudinal lines are scarcely visible. 3. Incomplete fracture following the opposite surfaces of a disk, which stretches across the interval and retains the two fragments in connexion. The edge and surface of this disk are seen to be minutely granular, the granules corresponding in size to the thickness of the disk, and to the distance between the faint longitudinal lines. 4. Another disk nearly detached. 5. Detached disk more highly magnified, showing the sarcous elements. (Bowman.)

[1] Philosophical Transactions, for 1842, Part i. p. 89.

[2] Art. Muscle, Cyclopædia of Anat. and Physiology, July, 1842, p. 508, and Physiological Anatomy and Physiology of Man, Part i., Lond., 1843.

that, on the contrary, violence causes a separation along the transverse dark lines, which always intersect the fibre in a plane perpendicular to its axis. By such a cleavage, disks and not fibrillæ are obtained; and this cleavage is as material as, although less frequent than, the former. Hence, he esteems it as proper to say, that the fibre is a pile of disks, as that it is a bundle of fibrillæ; that it is, in fact, neither one nor the other; but a mass in the structure of which there is an intimation of the existence of both, and a tendency to cleave in the two directions. If there were a general disintegration along all the lines in both directions, there would result a series of particles, which might be termed *primitive particles* or *sarcous elements*, the union of which would constitute the mass of the fibre; these elementary particles being arranged and united together in the two directions.

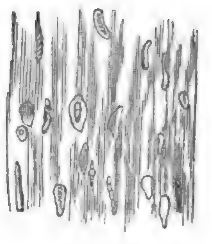
Gerber[1] is disposed to consider, that the "cross-streaking" frequently depends on the presence of a wrinkled fascicular sheath; "for when," he says, "the more superficial fibres chance to be removed, and the deeper ones exposed, these appear cylindrical, and the bundle at the part is longitudinally streaked. At the extremity of a torn fasciculus, too, the peripheral fibres often appear so distinctly marked off from the internal and more pulpy substance, that the existence of a more compact transversely streaked sheath can scarcely be called in question." Dr. Goddard[2] is of opinion, from his own observations, that the transverse striæ seem to be produced by a delicate thread of areolar tissue wound spirally around the ultimate fibrils, so as to hold them in a bundle; whilst Dr. Will[3] thinks that they are owing to the fibrils, which, in their natural relaxed state, are uniform and cylindrical, being thrown in contraction into undulations or zigzag flexures; and Valentin,[4] who has long described the relaxed muscular fibre as a uniform cylinder, confirms, generally, Dr. Will's account, although he cannot determine, whether the striated appearance of the fibrils be owing to their becoming varicose, or to zigzag flexures induced by contraction. He also maintains the view, long professed by him, that the fibres and fasciculi in the fully contracted state, are bent in zigzag lines, with angles of from 80° to 120°. The zigzag arrangement of fibres having the appearance of "series of rhomboidal pinnulæ, which immediately disappear as soon as the muscle ceases to act," was observed by Hales,[5] in the abdominal muscles of the frog.

Mr. Erasmus Wilson,[6] by resorting to peculiar methods of manipulation, and employing a microscope of more than ordinary power, believes that he has succeeded in discovering the real structure of the ultimate muscular fibril in a specimen taken from the arm of a strong healthy man immediately after amputation. He finds each fibril to be composed of minute cells disposed in a linear series, flattened at their surfaces of apposition, and so compressed in the longitudinal direction

[1] Elements of General and Minute Anatomy, by Gulliver, p. 251.
[2] Wilson's Anatomist's Vade Mecum, by Goddard, Amer. edit., p. 142, Philad., 1843.
[3] Müller's Archiv., 1843, Heft iv.
[4] Lehrbuch der Physiologie des Menschen, ii. 33, Braunschweig, 1844.
[5] Statical Essays, ii. 61, Lond., 1733.
[6] Proceedings of the Royal Society, June 20, 1844.

as to have no marginal indentation on the surface; thus constituting a uniform cylinder divided into minute subdivisions by transverse septa, which are formed by the adherent surfaces of contiguous cells. The diameter of the fibril, in the state of relaxation, is the 20,000th part of an inch. The cells are filled with a transparent substance, to which Mr. Wilson gives the name *myoline*, and which differs in its refractive density in different cells. In four consecutive cells, the myoline is of greater density than in the four succeeding cells, and this alternation is repeated throughout the whole course of the fibril. In consequence of all the fibrils composing the ultimate fasciculus having the same structure; and the cells, which are in lateral juxtaposition, containing myoline of the same density, they act similarly on light, and the whole presents to the eye of the microscopic observer a succession of striæ or bands, dark and luminous alternately, and transverse to the direction of the fasciculus; an appearance which has been noticed by previous observers, but the cause of which, according to Mr. Wilson, had not been before ascertained. A dark stria may occasionally appear as a luminous one, and conversely, when viewed by light transmitted at different degrees of obliquity. The structure here described, Mr. Wilson remarks, reduces the muscular fibre to the simple type of organization exhibited in the combination of a series of cells, associating it with other tissues of cell formation; and may probably, he thinks, open new sources of explanation of the immediate agency of muscular action,—a power which, as he properly observes, is involved in the deepest mystery.

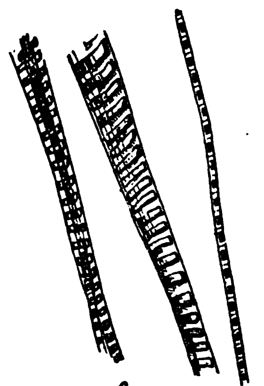
Fig. 154.



Mass of Ultimate Fibres from the Pectoralis Major of the Human Fœtus, at nine months. These fibres have been immersed in a solution of tartaric acid; and their "numerous corpuscles, turned in various directions, some presenting nucleoli," are shown.

One of the most recent views that have been published, is that of Dr. Sharpey[1] and Dr. Carpenter,[2] announced about the same time; according to which, each of the alternate light and dark particles of which the fibril is composed, has a quadrilateral and generally a rectangular form. Each bright particle or space is marked across its centre by a fine, dark, transverse line or shadow, by which the space is divided into two equal parts; and, at times, a bright border is perceptible on either side of the fibril, so that each of the rectangular dark bodies seems to be surrounded by a bright area, having a similar quadrangular outline, as if

Fig. 155.



Muscular Fibrils of the Pig. (After Sharpey.)

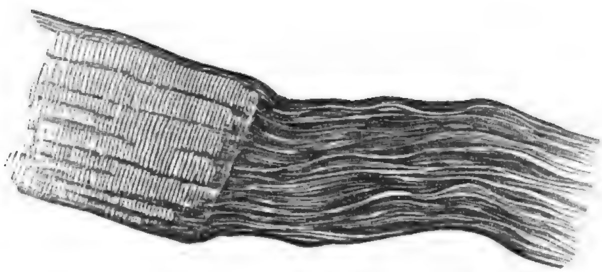
a. An apparently single fibril. *b.* Longitudinal segment of a fibre consisting of a number of fibrils connected together. *c.* Other smaller collections of fibrils.—Magnified 720 diameters.

[1] Human Anatomy, by Jones Quain, M. D., edited by Quain & Sharpey, Amer. edit., by Leidy, i. 316, Philad., 1849.
[2] Elements of Physiology, Amer. edit., p. 206, Philad., 1846.

the pellucid substance inclosed it on all sides;—appearances which have been considered to show, that the elementary particles of which the fibril is composed are little masses of pellucid substance, possibly nucleated cells, presenting a rectangular outline, and appearing dark in the centre.

The ultimate fibres or filaments, when united in bundles, form *fasciculi* or *lacerti;* and these, by their aggregation, constitute the various muscles. Each fibre, each lacertus, and each muscle, is surrounded by a sheath of areolar tissue, which enables them to move readily upon each other, and preserves them *in situ.* The fibres are not the same at the extremities as they are at the middle. The latter only consist of the proper muscular tissue; the extremities being formed of areolar tissue. If we examine a muscle, we find, that the proper muscular fibres become gradually fewer, and at length cease to be perceptible as they approach the tendon at one or other extremity. In this way, the areolar membrane, which surrounds every fibre, becomes freed from the muscular tissue; its divisions approximate, and become closely united and condensed, so as to form the *cord* or *tendon*, which, of course, holds a relation to each fibre of the muscle; and when they all contract, the whole force is exerted upon it. The microscopic observations of Mr. Bowman exhibited to him, that the component fibres of the tendinous structure are arranged with great regularity, parallel to

Fig. 156.



Attachment of Tendon to Muscular Fibre, in Skate. (Bowman.)

each other, and are attached to the end of the sarcolemma, which terminates abruptly, as in Figs. 148 & 156; which shows the attachment of the tendon to the muscular fibre in the skate. Dr. Leidy[1] observed that the filaments of areolar tissue, which form the sheaths of the muscular fasciculi, proceed, for the most part, in a diagonally crossing manner around the fasciculi, occasionally passing in between the fibres and intermingling with fine filaments of elastic tissue which exist in this situation. The sheaths are also connected together by filaments from them, which pursue the same diagonally crossing course. The filaments of the areolar sheaths become more or less straight at the extre-

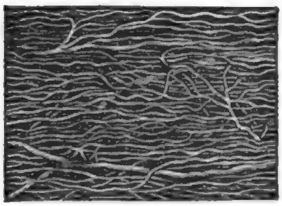
[1] Proceedings of the Academy of Natural Sciences of Philadelphia, vol. iv., No. 6, 1848; and Quain's Anatomy, by Quain & Sharpey, Amer. edit., by Leidy, i. 319, Philadelphia, 1849.

mities of the muscular fasciculi, and combine with the fibrous filaments originating there to form the tendinous connexion of the muscle.

The close union that exists between the muscle and its tendon formerly gave occasion to the belief, that the latter is only the former condensed. An examination of some of the physical and vital properties of the two will show, that they differ as essentially as any two of the constituents of the body that could be selected. The tendon consists chiefly of gelatin, and does not exhibit the same irritability; whilst the muscle is formed essentially of fibrin; and contracts under the will, as well as on the application of certain mechanical and chemical irritants. The differences, in short, that exist between the two, are such as distinguish the primary fibrous and areolar tissues; yet the opinion of their identity prevailed in antiquity; was embraced by Boerhaave and his school, and, as Dr. Bostock[1] observes, was so generally admitted even in the middle of the last century, that Haller[2] and Sabatier[3] scarcely ventured to give a decided opposition to it.

Similar remarks are applicable to the notion of Dr. Cullen,[4] that muscles are only the moving extremities of nerves. The fibres of the muscle were supposed by him to be continuous with those of the nerve; to be, indeed, the same substance, but changed in structure; so that when the nerve is converted into muscle, it loses the power of communicating feeling, and acquires that of producing motion.

Fig. 157.

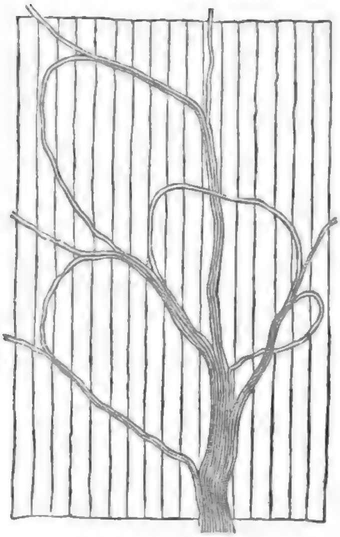


Capillary Net-work of Muscle.

Every muscle and every fibre of a muscle is probably supplied with bloodvessels, lymphatics, and nerves. These cannot be traced into the ultimate filament; but, as this must be possessed of life and be contractile under the will, it must receive through the bloodvessels and nerves the appropriate influences. MM. Dumas and Prévost,[5] and Mr. Bowman,—as has been remarked,—affirm, that the microscope shows, that neither the one nor the other terminates in the muscle. The vessels merely traverse the organs;—the arteries terminating in corresponding veins; so that the nutrition of muscles is effected by the transudation of plastic materials through the parietes of the artery, in the same manner probably as various other parts,—teeth, hair, cartilages, for example,—are nourished. A similar distribution is assigned by them to the nerves. All the branches, they assert, enter the muscle in a direction perpendicular to that of the fibres composing it; and their final ramifications, instead of terminating in the muscular fibres, surround them loopwise, and return to the trunk that furnished them, or anastomose with some neighbouring trunk. In their view, each nervous filament, distributed to the muscles, sets out from the anterior column of the

[1] An Elementary System of Physiology, 3d edit., p. 84, London, 1836.
[2] Elem. Physiol., ii. 1, 18. [3] Traité complet d'Anatomie, i. 242, Paris, 1791.
[4] Institutions of Medicine, §§ 29, 94; or Works of William Cullen, M.D., by John Thomson, M.D., i. pp. 15, 68, Edinb. and Lond., 1827.
[5] Magendie's Journal de Physiologie, tom. iii.

Fig. 158.



Loop-like termination of the Nerves in voluntary muscle.—After Burdach. (Todd and Bowman.)

spinal marrow, forming part of a nervous trunk; turns around one or more muscular fibres, and returns along the same or a neighbouring trunk to the posterior column of the marrow.

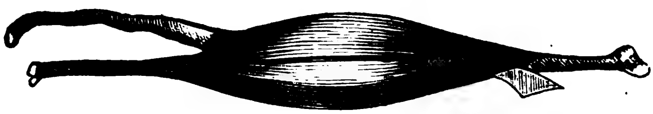
The red colour of muscles is usually ascribed to the blood distributed to them, as it may be removed by repeated washing and maceration in water or alcohol, without the texture of the muscle being modified. By some, it has been thought, that a quantity of red blood remains attached to the fibres, and is extravasated from the vessel: by others, it is presumed with more probability to be contained in the vessels, and according to Mulder,[1] who considers the red colour to be wholly due to the blood in the capillary system of the muscles, when they are injected with water, every muscle is colourless. Bichat[2] conceived, that the colour is dependent upon some foreign substance combined with the fibre; and he grounded his opinion upon the circumstance that, in the same animal, some of the muscles are always much redder than others, and yet they do not appear to have a greater quantity of blood sent to them; and also, that in different classes of animals the colour of the muscles does not appear to correspond with the quantity of red blood circulating through their vessels. The fact, however, that when muscles have been long in a state of inaction they become pale; and that, on the other hand, the colour becomes deeper when they are exercised, is additional evidence, that their colour is dependent upon the blood they receive, which is found to diminish or increase in quantity, according to the degree of inactivity or exertion.

Muscles differ, like the primary fibre, at their extremities and centre; the former being composed of condensed areolar membrane; the latter of the muscular or fibrous tissue. The centre of a muscle is usually called its *venter* or *belly;* and the areolar texture at the extremities is variously termed;—that from which it appears to arise being called the *head* or *origin;* and that into which it is inserted the *tail*, *termination* or *insertion*. These terms are not sufficiently discriminative. We shall find, that a muscle is capable of acting in both directions; so that the head and the tail—the origin and insertion—may reciprocally change places. In ordinary language, however, the extremity at which the *albugineous* tissue (if we adopt Chaussier's nomenclature), assumes a rounded form, so as to constitute a cord or *tendon*, is called the inser-

[1] The Chemistry of Vegetable and Animal Physiology, translated by Fromberg, &c., p. 589, Edinburgh and Lond., 1849. [2] Anat. Général., ii. 327, Paris, 1818.

tion. When this tissue is expanded into a membrane it is termed an *aponeurosis;* and in this state it exists at the head or origin of the muscle; so that by tendon and aponeurosis the muscles are inserted into the parts, which they are destined to move, if we except those that are inserted into the skin.

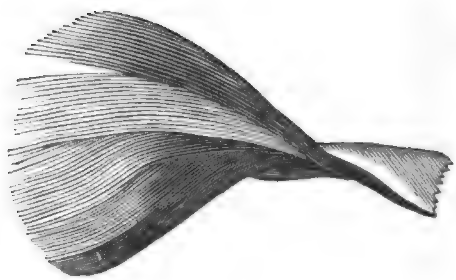
Fig. 159.



Compound Ventriform Muscle.

Muscles are divided into *simple* and *compound.* The *simple* are those whose fibres have a similar course and arrangement. They may be either *flat* or *ventriform*, *radiated* or *penniform.* The *compound* arise from different parts; their origins are, consequently, by distinct fasciculi, or they may terminate by distinct insertions. Fig. 159, which is a representation of the biceps—a flexor muscle of the forearm—is one of these. It has, as its name imports, two heads running into one belly. It is, also, an example of a *ventriform* muscle.

Fig. 160.



Penniform Muscle.

In the pectoralis major, Fig. 160, we have an example of the *radiated* muscle, or of one in which the fibres converge toward their tendinous insertion.

In the *penniform* muscle, the fibres run in a parallel direction, but are all inserted obliquely into the tendon, like the feathers of a quill. Fig. 161 is a representation of a *double penniform* muscle. Muscles may, also, be *complicated:* that is, with one belly, and several tendons having the fibres variously inserted into them; or having several bellies with the tendons interlaced.

Fig. 161.

Double Penniform Muscle.

They are, again, partitioned into the *long*, *broad*, and *short.* The *long* muscles are situate chiefly on the limbs, and are concerned in locomotion. The *broad* generally form the parietes of cavities: they are not so much enveloped as the long by strong fibrous aponeuroses

or fasciæ, owing to their being obviously less liable to displacement; and the *short* are situate in parts, where considerable force is required, and but little motion; so that their fibres are very numerous.

The number of muscles varies, of course, in different animals, in proportion to the extent and variety of motion they are called upon to execute. In man, it is differently estimated by anatomists; some describing several distinct muscles under one name; and others dividing into many what ought to belong to one. According to the arrangement of M. Chaussier, three hundred and sixty-eight distinct muscles are admitted; but others reckon as many as four hundred and fifty.

When muscles are subjected to analysis, they are found to consist of fibrin; osmazome; jelly; albumen; phosphates of soda, ammonia, and lime; carbonate of lime; chloride of sodium; phosphate, and lactate of soda; and, according to Fourcroy and Vauquelin,[1] sulphur and potassa are present. The great constituents of the pure muscular tissue are,—fibrin, and probably osmazome;—the gelatin met with being ascribable to the areolar membrane that envelopes the muscular fibres and lacerti. The membranous structures of young animals contain a much greater quantity of jelly than those of the adult; and it is probably on this account, that the flesh of the former is more gelatinous; not because the muscular fibre contains more gelatin. M. Thénard assigns the muscles, on final analysis, the following constituents:—fibrin; albumen; osmazome; fat; substances capable of passing to the state of gelatin; acid (lactic), and different salts: kreatin and kreatinin have likewise been found in them. They have also been analyzed by Berzelius and Braconnot[2] and others. It must be borne in mind, however, as M. Raspail[3] has properly remarked, that all these are the results of the analysis of muscle, as we meet with it. The analysis of muscular fibre has yet to be accomplished. In this, too, and every analogous case, the analysis only affords us evidence of the constituents of dead animal matter; and some of the products may even have been formed by new affinities resulting from the operations of the analyst. They can afford but an imperfect judgment of the constitution of the living substance. These remarks are especially applicable to the efforts at determining the composition of muscle by ultimate analysis. Mulder,[4] indeed, affirms, that this is impracticable—"for in this process we burn a mixture of various substances, a very complicated tissue of muscular fibres, ligamentary tissue, coats of bloodvessels and nerves. If, therefore, Playfair and Böckmann have found the composition of muscle to be identical with that of blood,—which is a mixture of various substances, containing some that are entirely different from those of muscle, and in which again others are wanting that are present in the latter,—then this may be considered as

[1] Annales de Chimie, lvi. 43.

[2] Müller's Handbuch der Physiologie, Baly's translation, Part i. p. 369, Lond., 1837; and Dr. T. Thomson, Chemistry of Animal Bodies, p. 273, Edinb., 1843.

[3] Op. citat., p. 214.

[4] The Chemistry of Vegetable and Animal Physiology, by Fromberg, &c., p. 589, Edinb. and Lond., 1849.

a proof that it is impossible to find out essential differences by means of ultimate analysis:"—and he adds—"Nothing has ever surprised me more than the assertions now so frequently repeated, that muscle and blood are identical in composition—two substances which present, in fact, no other point of resemblance, except this, that they both contain protein compounds. But if we proceeded upon this principle, we should be induced at present to apply the term identity to a great number of substances indeed."

Muscular structure is liable, under particular circumstances, to a singular kind of conversion, to which it may be well to advert. When, about the latter part of the last century, it was determined, for purposes of salubrity, to remove the bodies from the churchyard of *Les Innocens* at Paris[1]—which had been the cemetery for a considerable part of the population of Paris for centuries; the whole area, occupying about seven thousand square yards, was found converted into a mass, consisting chiefly of animal manner, and raising the soil several feet above the natural level. On opening the ground, to remove the prodigious collection of dead bodies, they proved to be strangely altered in their nature and appearance. What had constituted the soft parts of the body was converted into an unctuous matter, of a gray colour, and peculiar, but not highly offensive, smell. According to their position in the pits,—for the bodies were deposited in pits or trenches, about thirty feet deep, each capable of holding from twelve hundred to fifteen hundred,—and according to the length of time they had been deposited, this transformation had occurred to a greater or less extent. It was found to be most complete in those that were nearest the centre of the pits, and when they had been buried about three years. In such case, every part, except the bones, hair and nails, seemed to have lost its properties, and to be converted into *gras des cimetières*, which was found to be a saponaceous compound, consisting of ammonia, united to *adipocire*,—a substance, as its name imports, possessing properties intermediate between those of fat and wax. When the adipocire was freed from the ammonia, and obtained in a state of purity, it was found to resemble strongly spermaceti, both in physical and chemical qualities. It was afterwards discovered, that the conversion of muscular flesh into adipocire might be caused by other means. Simple immersion, in cold water, especially in a running stream, was found by Dr. Gibbes[2] to produce the conversion more speedily than inhumation. It can be caused, too, still more rapidly by the action of dilute nitric acid.

The chemical is not the only interest attached to this substance. It has been adduced in a court of justice for the purpose of enabling some judgment to be formed regarding the time that a body may have been immersed in the water. It is probable that this must differ greatly according to various circumstances;—as the period that elapsed between the death of the individual, and the act of immersion; the conditions of the fluid as to rest or motion, temperature, &c.; and the

[1] Thouret, Journal de Physique, xxxviii. 255.
[2] Philosophical Transactions for 1794 and 1795.

temperature of the atmosphere; so that any effort to fix a time for such conversion must be liable to much inconclusiveness. Yet the opinion of a medical practitioner on the subject has been the foundation of a juridical decision. At the Lent assizes, holden at Warwick, England, in the year 1805, the following case came before the court. A gentleman, who was insolvent, left his home with the intention,—as was presumed from his previous conduct and conversation,—of destroying himself. Five weeks and four days after that period, his body was found floating down a river. The face was disfigured by putrefaction, and the hair separated from the scalp on the slightest pull; but the other parts of the body were firm and white, without any putrefactive appearance. On examining the body, it was found that several parts were converted into adipocire. A commission of bankruptcy having been taken out against the deceased a few days after he left home, it became an important question to the interest of his family to ascertain whether or not he was living at that period. From the changes sustained by the body, it was presumed, that he had drowned himself on the day he left home; and to corroborate the presumption, the evidence of Dr. Gibbes was requested, who, from his experiments on this subject, it was thought, was better acquainted with it than any other person. Dr. Gibbes stated on the trial, that he had procured a small quantity of this fatty matter, by immersing muscular parts of animals in water for a month, and that it required five or six weeks to form it in any large quantity. Upon this evidence, the jury were of opinion, that the deceased was *not alive* at the time the commission was taken out, and the bankruptcy was accordingly superseded![1]

Bones.

The bones are the hardest parts of the animal frame; and serve as a base of support and attachment to the soft parts. They constitute the framework of the body, and determine its general shape. The principal functions they fulfil are,—to form defensive cavities for the most important organs of the body,—the encephalon, spinal-marrow, &c.—and to act as so many levers for transmitting the weight of the body to the soil, and for the different locomotive and partial movements. To them are attached the different muscles, concerned in those functions. In man and the higher classes of animals, the bones are, as a general rule, within the body; his *skeleton* is, consequently, said to be internal. In the crustacea, the testaceous mollusca, and certain insects, the skeleton is external; the whole of the soft parts being contained within it. The lobster and crab are familiar instances of this arrangement.

The stature of the human skeleton is various, and may be taken, on the average, perhaps,—in those of European descent,—at about five feet seven and a half inches.[2] We find, however, examples of considerable variation from this average. A skeleton of an Irish giant,

[1] Male, Epitome of Forensic Medicine, in Cooper's Tracts on Medical Jurisprudence, Philad., 1819.

[2] Quetelet, Sur l'Homme, &c., Paris, 1835; or translation by Dr. Knox, p. 64, Edinb., 1842.

in the museum of the Royal College of Surgeons of London, measures eight feet four inches. On the other hand, Bebe, the dwarf of Stanislaus, King of Poland, was only thirty-three inches high; and a Polish nobleman, Boruwlaski, is said to have measured twenty-eight French inches, at twenty-two years of age. Mr. Mathews, the comedian, states, however, that he measured him late in life and found that his height was three feet three inches; and that he had undoubtedly grown an inch a short time before he was eighty-one, when he measured three feet four.[1] He had a sister, whose height was twenty-one inches.[2] Sir George Simpson,[3] in one of the villages of Siberia, saw a dwarf, about forty years of age, thickset, with a large head, and barely two feet and a half high. "For his inches, however," says Sir George, "he was a person of great importance, being the wise man of the place, and the great arbiter in all disputes, whether of love or of business." The celebrated dwarf called General Tom Thumb, was seen by the author in 1847. He was then said to be fifteen years old; weighed at the Mint twenty pounds and two ounces, and was twenty-eight inches high. His intellect was evidently limited, childlike.

The bones may be divided into *short*, *broad*, or *flat*, and *long*. *Short* bones are met with in parts of the body, which require to be both solid and movable:—in the hands and feet, for example; and in the spine. *Flat* or *broad* bones form the parietes of cavities, and aid materially in the movements and attitudes, by affording an extensive surface for the attachment of muscle. *Long* bones are chiefly intended for locomotion; and are met with only in the extremities. The shape of the *body* or *shaft* and of the *extremities of a bone*, merits attention. The shaft or middle portion is the smallest in diameter, and is usually cylindrical. The extremities, on the other hand, are expanded; a circumstance, which not only adds to the solidity of the articulations, but diminishes the obliquity of the insertion of the tendons, passing over them, into the bones. In their interior is a medullary canal or cavity, which contains the *medulla*, *marrow* or *pith:*—a secretion, whose office will be a theme for after inquiry. One great advantage of this canal is, that it makes the bone a hollow cylinder, and thus diminishes its weight. On many of the bones, prominences and cavities are perceptible. The eminences bear the generic name of *apophyses* or *processes*. Their great use is to cause the tendons to be inserted at a much greater angle into the bones they have to move. It may be seen, hereafter, that the nearer such insertion is to the perpendicular to the lever, the greater will be the effect produced.

The cavities are of various kinds. Some are *articular:* others for the insertion, reception, or transmission of parts. Those of insertion and reception afford space for attachment of muscles; those of transmission, &c., are frequently incrusted with cartilage; converted into canals by means of ligament, and furnished with a synovial membrane,

[1] A Continuation of the Memoirs of Charles Mathews, Comedian, by Mrs. Mathews, Amer. edit., i. 165, Philad., 1839.

[2] Lectures on Physiology, Zoology, &c., by W. Lawrence, p. 434, Lond., 1819.

[3] An Overland Journey round the World, Amer. edit., Part ii. p. 203, Philad., 1847.

which lubricates them; and facilitates the play of the tendons, for the passage of which they are destined.

The mechanical structure of bone is a laminated framework incrusted by an earthy substance, and penetrated by exhalant and absorbent vessels, arteries, veins and nerves. M. Herissant[1] appears to have been one of the first who stated, that bone is essentially composed of two substances:—the one a cartilaginous basis or parenchyma, giving form to the part;—the other a peculiar earthy matter deposited on this basis, and communicating to it hardness. These two constituents can be readily demonstrated; the first, by digesting the bone in dilute chlorohydric acid, which dissolves the earthy part, without acting on the animal matter; and the second, by burning the bone until all the animal matter is consumed, whilst the earthy is left untouched.

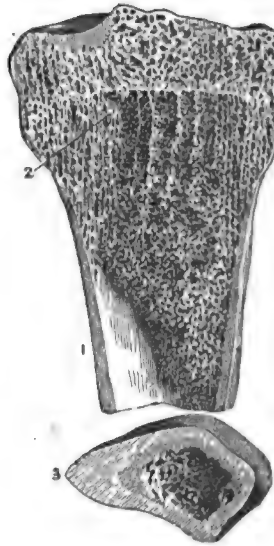
If we take a long bone and divide it longitudinally, we find, that it is composed of three different substances, all of which may, however, be regarded as the same osseous tissue in various degrees of condensation. These are,—the *hard* or *compact* substance; the *spongy* or *areolar;* and the *reticulated.* The first is in the most condensed form; it exists at the exterior of the bone, and constitutes almost the whole of the shaft. The second is seen towards the extremities of a long bone, and in almost the whole of the short bones. In it, the laminæ are less close, and have a cancellated appearance,—the cellules bearing the name of *cancelli.* The reticulated substance is a still looser formation; the laminæ being situate at a considerable distance; and the space between filled up with a series of membranous cells, which lodge the marrow. The marginal figures represent a longitudinal and a transverse section of the same bone, in which this arrangement is well exhibited.

We have seen the advantages of the expanded extremities of long bones, as regards the insertion of muscles; but it is obvious, that if these portions of the bone had consisted of the heavy compact tissue, the increased weight would have destroyed the advantages, that would otherwise have accrued; whilst, if the shaft of the bone, exposed, as it is, to external violence, had consisted of the spongy tissue only, it would not have offered the necessary resistance. It is, therefore, formed almost entirely of the compact tissue; so that a section of one inch, taken from the body of the bone, will not differ essentially in weight from an inch taken from the extremity. Nor does the cavity within the bones diminish their strength, as might at first sight be presumed. By enlarging the circumference, the contrary effect is produced; for we shall see, in the mechanical proem to the particular movements, that of two hollow columns, formed of an equal quantity of matter and of the same height, that, which has the larger cavity, is actually the stronger. A very important use of the cancellated or spongy texture of the bones was suggested by a distinguished individual of this country, to whom surgical science, in particular, has been largely indebted. Dr. Physick[2] asserts, that it serves to diminish, and, in many cases, to prevent, con-

[1] Mémoir. de l'Académ. des Sciences de Paris, pour 1758, p. 322.
[2] Horner, Special and General Anatomy, &c., 5th edit., Philad., 1843.

cussion of the brain, and of other viscera, in falls and blows. The demonstration, which he gives of this, is simple and satisfactory. If we suspend a series of six ivory balls by threads; raise the ball at one extremity of the series, and allow it to fall on the next to it, the farthest ball in the series is impelled to a distance which corresponds with the momentum communicated by the first ball to the second. But if we substitute, for the middle ball of the series, a ball made of the cellular structure of bone, almost the whole of the momentum is lost in this osseous structure; especially, if it be previously filled with tallow or well soaked in water, so as to bring it to a closer approximation to the living condition.

Fig. 162.



Sections of a Bone.

1, 2. Longitudinal section of the extremity.
3. Transverse section of the body.

Bones consist of earthy salts, and animal matter, intimately blended. The latter is chiefly cartilage, gelatin, and the peculiar fatty matter—the marrow. On reducing bones to powder, and digesting them in water, the fat rises and swims upon the surface; and the gelatin is dissolved. According to the analysis of Berzelius, 102 parts of dry human bones consist of animal matter, 33·3; basic phosphate of lime, 51·04; carbonate of lime, 11·30; fluoride of calcium, 2; phosphate of magnesia, 1·16; soda, chloride of sodium, and water, 1·2. It has been much doubted, however, whether fluoride of calcium is contained in recent bones; whilst it is admitted to have been detected in fossil bones. According to Dr. Daubeny,[1] it exists in the former, in about a quarter of the proportion in which it is present in the latter; but the proportions in different specimens of both kinds are variable. Dr. Daubeny ascribes the failure of those who have not detected fluorine except in fossil bones and teeth, to the tenacity with which it is retained by animal matter; and to its being carried off with the carbonic acid evolved at the same time, too rapidly to act upon glass exposed to it. He, therefore, before submitting the bones to the action of strong sulphuric acid, burns away all the animal matters; removes the carbonic acid by dissolving them in chlorohydric acid; then throws down the earthy phosphates by caustic ammonia, and dries them.

MM. Fourcroy and Vauquelin found in bones oxides of iron and manganese, silica, and albumen. Mr. Hatchett detected, also, a small quantity of sulphate of lime. Schreger gives the following as the proportions of the animal and earthy parts:

	Infants.	Adults.	Aged.
Animal matter	47·20	20·18	12·20
Earthy matter	48·48	74·84	84·10
	95·68	95·02	96·30

[1] Philosophical Magazine, Aug., 1844.

The following are the average proportions, according to Lehmann,[1] from his own analyses, and those of two other observers.

	Sebastian.	Lehmann.	Frerichs.	
			Compact Bone.	Spongy Bone.
Organic . .	63·66	32·28	31·2	37·82
Earthy . .	63·34	67·72	68·8	62·18

Dr. Stark[2] affirms, from the results of his experiments, that the mean proportion of animal matter in the bones of all vertebrate animals is 33·91; of earthy 66·09; the mean proportion in the bones of man 33·39 of animal matter; 66·61 of earthy.

The bones are enveloped by a dense fibrous membrane, termed, in the abstract, *periosteum;* but assuming different names according to the part it covers. On the skull, it is called *pericranium:* and its extensions over the cartilages of prolongation are called *perichondrium.* The chief uses of this expansion are, to support the vessels in their passage to and from the bone, and to assist in its formation; for we find, that if the periosteum be removed from a bone, it becomes dead at the surface previously covered by the membrane, and exfoliates. In the fœtus, it adds materially to the strength of bone, prior to the completion of ossification. In the long bones, ossification commences at particular points; one generally in the shaft, and others at the different articular and other processes. These ossified portions are, for some time, separated from each other by the animal matter, which alone composes the intermediate portions of the bone; and, without this fibrous envelope, they would be too feeble, perhaps, to resist the strains to which they are exposed. The periosteum, moreover, affords a convenient insertion for muscles destined to act upon bones; and enables them to slide more readily when contracting: hence friction is avoided.

The cavity of long bones is lined by a membrane—called *medullary membrane* or *internal periosteum*—which is supplied with numerous vessels; adheres to the internal surface of bone, and is not only concerned in its nutrition, but in the secretion of the *marrow*, and likewise of a kind of oily matter, which differs from marrow in being more fluid, and is contained in cells formed by the spongy substance, and in areolæ of the compact substance. This is called *oil of bones.*

Marrow is considered to be lodged in membranous cells, formed by an extension of the internal periosteum; whilst, according to Mr. Howship,[3] oil of bones is probably deposited in longitudinal canals—*Haversian canals*—which traverse the solid substance of the bone, and through which its vessels are transmitted. If a thin transverse section of long bone be examined under a high magnifying power, the bony matter is observed to be arranged in concentric circles around the orifices of the canals as in Fig. 164. These circles are marked by a number of stellated dark spots formerly termed *osseous corpuscles;* but as they are minute cavities in the bony substance, now more appropriately called *lacunæ.* From these, fine pores or tubes, termed *canaliculi*, proceed,

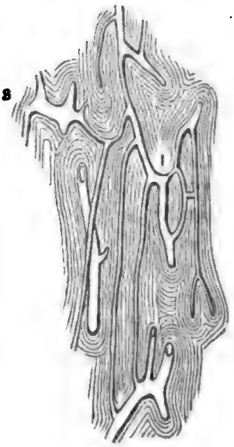
[1] Schmidt's Jahrbucher, No. vi., 1843.
[2] Edinburgh Medical and Surgical Journal, April, 1845, p. 313.
[3] Medico-Chirurg. Transact., vii. 393.

which traverse the substance of the bone, and communicate irregularly with each other. All the different lacunæ communicate by means of the canaliculi with the Haversian canals; so that fluid may pass to every part of the osseous substance, and thus convey fluid for nutrition. They open, likewise, into the great medullary canal, and into the cavities of the cancellated texture. Blood corpuscles cannot pass along them, as their largest diameter has not seemed to be more than from 1-20000th to 1-14000th of an inch; and the smallest not more than from 1-60000th to 1-40000th.

The nature and fancied uses of marrow and oil of bones will be considered elsewhere.

The bones, periosteum, and marrow are, in the sound state, amongst the insensible parts of the frame. They are certainly not sensible to ordinary irritants; but, when morbid, exhibit intense sensibility. This applies, at least, to bones and the periosteum; the sensibility, which has been ascribed to the marrow, in disease, being probably owing to that of the prolongations of the membrane in which it is contained.

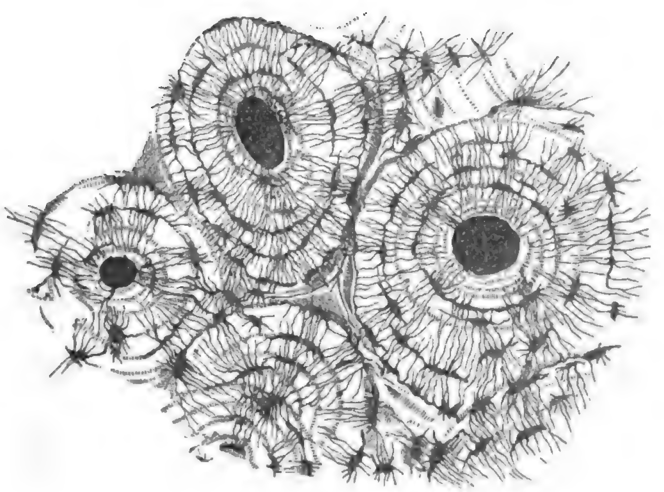
Fig. 163.



Haversian Canals, seen on a Longitudinal Section of the Compact Tissue of the Shaft of one of the Long Bones.

1. Arterial canal. 2. Venous canal. 3. Dilatation of another venous canal.

Fig. 164.



Transverse Section of Compact Tissue of Humerus magnified about 150 diameters.

Three of the Haversian canals are seen, with their concentric rings; also the corpuscles or lacunæ, with the canaliculi extending from them across the direction of the lamellæ. The Haversian apertures had got filled with debris in grinding down the section, and therefore appear black in the figure, which represents the object as viewed with transmitted light.

The number of the bones in the body is usually estimated at two hundred and forty, exclusive of the *sesamoid*, which are always found

in pairs at the roots of the thumb and great toe; between the tendons of the flexor muscles and joints; and, occasionally, at the roots of the fingers and small toes.

The bones are connected by means of *articulations* or *joints*, which differ materially from each other. To all the varieties, names are appropriated, which form a difficult task for the memory of the anatomical student. Technically, every part at which two bones meet, and are connected, is called an *articulation*, whether any degree of motion exists or not. This, indeed, is the foundation of the division that prevails at the present day,—the articulations being separable into two classes; the *immovable* or *synarthroses;* and the *movable* or *diarthroses. Synarthroses* are variously termed, according to their shape. When the articular surfaces are dovetailed into each other, the joint is called a *suture.* This is the articulation that prevails in the bones of the skull. *Harmony* is when the edges of bones are even, and merely touch; as in the bones of the head in quadrupeds and birds. When a pit in one bone receives the projecting extremity of another, we have a case of *gomphosis.* It is exhibited in the union between the teeth and their sockets. Lastly, *schindylesis* is when the lamina of one bone is received into a groove of another; as in the articulation of the vomer, which separates the nasal fossæ from each other. The *movable articulations* comprise two orders:—*amphiarthroses*, in which the two bones are intimately united by an intermediate substance, of a soft and flexible character, as in the junction of the vertebræ with each other; and *diarthroses*, properly so called. The last admit of three subdivisions—*enarthroses* or *ball and socket joints;* the *condyloid*, in which, owing to the head being oval, the movements are not as easy in all directions as when it is spherical; and the *ginglymoid* or *ginglymus*, in which the motion can occur in only one direction, as in a hinge. The farther subdivision of the joints belongs more to anatomy than to physiology.

The articular surfaces of bones never come into immediate contact. They are tipped with a firm, highly elastic substance, called *cartilage;* which, by its smoothness, enables the bones to move easily upon each other; and may have some influence in deadening shocks, and defending the bones, which it covers. The arrangement of cartilage varies according to the shape of the extremity of the bone. If it be spherical, the cartilage is thick at the centre, and gradually diminishes towards the circumference. In the cavity, the reverse is the case; the cartilage is thin at the centre, and becomes thicker towards the circumference; whilst on a trochlea or pulley its thickness is nearly every where alike.

An admirable provision against displacement of bones at the articulations is seen in the ligaments. These, by the French anatomists, are distinguished into two kinds—*fibrous capsules*, and *ligaments* properly so called. The former are a kind of cylindrical sac, formed of a firm, fibrous membrane; open at each extremity, by which they closely embrace the articular ends of bones; and loose, when the joint admits of much motion. In this way, the articulation is completely enclosed: they generally bear the name of *capsular ligaments.* The *ligaments*, properly so called, are bands of the same kind of tissue, which extend

from one bone to another; by their resistance preserving the bones *in situ;* and by their suppleness admitting the necessary motion.

The interior of all these articulations is lubricated by a viscid fluid, called *synovia.* This is secreted by a peculiar membrane of a serous nature; and its use is to diminish friction, and, at the same time, to favour adhesion. The mode in which it is secreted, and its chief properties and uses, will be the subject of future inquiry.

In certain of the movable articulations, fibro-cartilaginous substances, frequently called *interarticular cartilages*, are found between the articular surfaces, and not adherent to either. These have been supposed to form a kind of cushion, which, by yielding to pressure, and returning upon themselves, may protect the joints to which they belong; and, accordingly, it is asserted, that they are met with in joints, which have to sustain the greatest pressure; but M. Magendie[1] properly remarks, that they do not exist in the hip or ankle-joint, which have constantly to support the strongest pressure. The use, which he suggests, is more specious;—that they may favour the extent of motion, and prevent displacement.

The stability of the joints is likewise aided by the manner in which muscles or tendons pass over them. These are contained in an aponeurotic sheath, to prevent their displacement; and thus the whole limb becomes well protected, and dislocation unfrequent, even in those joints, as that of the shoulder, which, as regards their osseous arrangement, ought to be very liable to displacement.

It has been suggested by Weber, that the head of the thigh-bone is retained *in situ*, not by the power of the muscles or ligaments, but by the pressure of the surrounding atmosphere; and Lauer,[2] who repeated Weber's experiments under the directions of Fricke, of Hamburg, is of opinion, that atmospheric pressure must be classed among the means by which the lower extremity is kept in apposition with the trunk of the body.

PHYSIOLOGY OF MUSCULAR MOTION.

By *voluntary motion* or that effected by the *muscular system of animal life*, we mean contraction of the muscles under the influence of *volition* or *will.* This influence is propagated along the nerves to the muscles, which are excited by it to contraction. The *encephalon*, *spinal marrow*, *nerves*, and *muscles* are, therefore, organs of voluntary muscular contraction.

Volition is a function of the encephalon, and might have been with much propriety included under the physiology of the intellectual and moral acts; but as it is so intimately concerned with muscular motion, it was judged advisable to defer its consideration. That in man and the higher animals, it is a product of encephalic action is proved by many facts. If the brain be injured in any manner;—by fracture of the skull, or by effusion of blood, producing apoplectic pressure;—or if it be deprived of its functions by a strong dose of any narcotic substance;—

[1] Précis Elémentaire, 2de édit., i. 292, Paris, 1823.
[2] Zeitschrift fur die gesammte Medicin, Band ii. Heft 3.

or if, again, it be in a state of rest, as in sleep;—volition is no longer exerted; and voluntary motion is impracticable. This is the cause why the erect attitude cannot be maintained during sleep; and why the head falls forward upon the chest, when somnolency is to such an extent as to deprive the extensor muscles of the back and head of their stimulus to activity.[1] That an emanation from the encephalon is necessary is likewise proved by the effect of tying, cutting, compressing, or stupefying a nerve proceeding to a muscle; it matters not that the will may act; the muscle does not receive the excitation, and no motion is produced; a fact which proves, that nerves are the channels of communication between the brain and the muscles. If, again, we destroy the medulla oblongata and medulla spinalis, we abolish all muscular motion, notwithstanding the brain may will, and the muscles be in a state of physical integrity; because we have destroyed the parts whence the nerves proceed. In like manner, by successively slicing away the medulla spinalis from its base to the occiput, we paralyse, in succession, every muscle of the body that receives its nerves from the spinal marrow.

Experiments of physiologists have confirmed the view, that the encephalon is the chief seat of volition. When it has been sliced away to a certain extent, the animal has been thrown into a state of stupor, attended with loss of sensibility, power of locomotion, and especially spontaneous motion; and in writing, dancing, speaking, &c., we have indisputable evidence of its direction by the intellect. It is not so clear, that the seat of volition is restricted to the encephalon. There are actions of the yet living trunk, which appear to show, that an obscure volition may be exerted even after the brain has been separated from the rest of the body; and acephalous children have not only moved perceptibly when in utero, but at birth. Without referring to the lowest classes of animals, which execute voluntary motions for a long time after they have been bisected, every one must have noticed the motions of decapitated fowls, which continue for a time, to run and leap, and apparently, to suffer uneasiness in the incised part.

The feats of the Emperor Commodus are elucidative of this matter. Herodian relates, that he was in the habit of shooting at the ostrich, as it ran across the circus, with an arrow having a cutting edge; and, even when the shaft was true to its destination, and the head was severed from the body, it usually ran several yards before it dropped. Kaauw Boerhaave—nephew of the celebrated Hermann, himself an eminent medical teacher at St. Petersburg—asserts that he saw a cock, thus decapitated, run a distance of twenty-three feet. Cases are also recorded of men walking a few steps after decapitation, striking their breasts, &c.; but they can scarcely be regarded as authentic.[2] In countries where judicial execution consists in decapitation by the sword, sufficient opportunities must have presented themselves for testing this question; but no zealous Naturforscher appears to have been pre-

[1] Adelon, art. Encéphale (Physiol.) in Dict. de Méd., vii. 516, Paris, 1823; and Physiol. de l'Homme, ii. 25, 2de édit., Paris, 1829.

[2] Adelon, op. citat., ii. 28; and Dr. J. R. Coxe, in Dunglison's Amer. Med. Intelligencer, for May 15, 1837.

sent to record them. Similar opportunities have likewise occurred under the operations of the guillotine.

M. Legallois,[1] in some experiments, which he instituted, for the purpose of determining the nervous influence on the heart, &c., found that rabbits, which he had deprived of their heads and hinder extremities, but still kept alive by artificial respiration, moved their fore paws whenever he stimulated them by plucking their hairs.

With regard to complete acephali, or those fœtuses which are totally devoid of encephalon,—although they may vegetate in utero, they expire after birth, owing to their being devoid of the medulla oblongata in which is the nervous system of respiration. Monsters have been born without the brain, but with part of the encephalon. These have been called, by way of distinction, *anencephali* or *hemicephali*. Where the medulla oblongata exists, they possess the nervous system of the senses, and of respiration, and are, consequently, able to live for a time after birth, and to exert certain muscular movements, as sucking, moving the limbs, evacuating the excretions, &c. M. Adelon asserts, that none of these facts ought to shake the proposition,—that in the superior animals, and consequently in man, the medulla spinalis and nerves are merely the conductors of volition or the locomotive will; and that volition is produced in the encephalon alone. His arguments on this point are not, however, characterized by that ingenuousness and freedom from sophism, for which his physiological disquisitions are generally distinguished. "First of all," he observes, "the fact of the progression and motions of men and quadrupeds after decapitation is manifestly apocryphal; and even if we admit, that certain animals still execute certain movements after decapitation, are such evidently regular and ordained? And, supposing them to be so, may not this have arisen from the conformation of the parts, or from habits contracted by the organs? This last appears to us most probable; for if, from any cause whatever, the muscles of a part contract, they cause the part to execute such motions as the joints, entering into its composition, require; and which may, therefore, be similar to those produced by the will." He further attempts to deny the facts related of the lower classes of animals, and asserts, that "they are not evinced in the experiments instituted in our day." The cases, recorded to prove the defective sensibility of the lower tribes of animated nature, are, however, as has been elsewhere shown, incontestable.—The trunk of the wasp attempts to sting after the head has been removed; and an experiment made on the rattlesnake by Dr. Harlan,[2] in the presence of Capt. Basil Hall, certainly demonstrates something like design in the headless trunk; and the cases, already referred to, on the authority of Drs. Le Conte and Dowler, exhibit almost miraculous phenomena of the kind in the decapitated alligator.[3]

Our conclusion ought probably to be, from all these cases,—that volition is chiefly seated in the encephalon, but that an obscure action of the kind may originate, perhaps, farther down the cerebro-spinal

[1] Œuvres, Paris, 1824.

[2] Medical and Physical Researches, Philad., 1835.

[3] See p. 307.

axis. This conclusion, of course, applies only to the higher classes of animals; for we have seen, that the polypus is capable of division into several portions, so as to constitute as many distinct beings; and it is probable, that the principal seat of volition may extend much lower down in the inferior tribes of created beings.

Successful attempts have been made to discover, whether the whole brain is concerned in volition, or only a part. Portions have been disorganized by disease, and yet the person has not been deprived of motion; at other times, as in paralysis, the faculty has been impaired; and again, considerable quantities of brain have been lost, owing to accidents (in one case the author knew nineteen tea-spoonfuls), with equal immunity as regards the function in question. Experiments, executed on this subject, go still farther to confirm the idea, that volition is not seated exclusively in the encephalon. MM. Rolando and Flourens[1] performed several, with the view of detecting the seat of the locomotive will, or of that which presides over the general movements of station and progression; and they were led to fix upon the cerebral lobes. Animals, from which these were removed, were thrown into a sleepy, lethargic condition; were devoid of sensation and spontaneous motion, and moved only when provoked. On the other hand, M. Magendie[2] affirms, that the cerebral hemispheres may be cut deeply in different parts of their upper surface, without any evident alteration in the movements. Even their total removal, if it did not implicate the corpora striata, he found to produce no greater effect; or, at least, none but what might be easily referred to the suffering induced by such an experiment. The results, however, were not alike in all classes of vertebrated animals. Those mentioned were observed on quadrupeds, and particularly dogs, cats, rabbits, Guinea-pigs, hedgehogs, and squirrels. In birds, the removal or destruction of the hemispheres—the optic tubercles remaining untouched—was often followed by the state of stupor and immobility described by MM. Rolando and Flourens; but, in numerous cases, the birds ran, leaped, and swam, after the hemispheres had been removed, the sight alone appearing to be destroyed. In reptiles and fish, the removal of the hemispheres seemed to exert little effect upon their motions. Carps swam with agility; frogs leaped and swam as if uninjured; and their sight did not appear to be affected. Magendie[3] properly concludes, from these experiments, that the spontaneity of the movements does not belong exclusively to the hemispheres; that in certain birds, as the pigeon, adult rook, &c., this seems to be the case; but not so in other birds. To mammalia, reptiles, and fish,—at least such of them as were the subjects of experiment,—his conclusion is, however, applicable.

Of the nature of the action of the brain in producing volition we know nothing. It is only in the prosecution of direct experiments on the encephalon that we can have an opportunity of seeing it during the execution of the function; but the process is too minute to admit of observation. Our knowledge is confined to the fact, that the encephalon acts, and that some influence is projected from it along the muscles,

[1] Op. citat. [2] Précis Elémentaire. [3] Ibid., i. 336.

which excites them to action; and accurately regulates the extent and velocity of muscular contraction. Yet volition is not the sole excitant of such contraction. If we irritate any part of the encephalon or spinal marrow, or any of the nerves proceeding from them, muscular movements are excited; but they are not regulated as when under the influence of volition. The whole class of *involuntary motions*, or rather of those executed by the *muscular system of organic life*, is of this kind, including the action of many of the most important organs,—heart, intestines, blood-vessels, &c. The involuntary muscles equally require a stimulus to excite them into action; but, as their name imports, they are removed from the influence of volition. In certain diseased conditions, we find, that all the voluntary muscles assume involuntary motions; but this is owing to the ordinary volition being interfered with, and to some direct or indirect stimulation affecting the parts of the cerebro-spinal axis concerned in muscular contraction; or, if the effect be local, to some stimulation of the nerve proceeding from the axis to the part. Of this kind of general involuntary contraction of voluntary muscles, we have a common example in the convulsions of children; and one of the partial kind, in cramp or spasm.

The will, then, is the great but not the sole regulator of the supply of voluntary nervous influence. This is confirmed by experiment. If a portion of the spinal marrow be divided, so as to separate it from all communication with the encephalon, the muscles cannot be affected by the will; but they contract on irritating the part of the spinal marrow, from which its nerves proceed. It has, hence, been presumed by some physiologists, that volition is only the exciting and regulating cause of the nervous influx; and that the latter is the immediate agent in producing contraction; and they affirm, that as, in the sensations, the impression is made on the nerve, and perception effected in the brain,—so, in muscular motion, volition is the act of the encephalon, and the nervous influx to a part corresponds to the act of impression.

With regard to the seat of this nervous centre of muscular contraction, much discrepancy has existed amongst modern physiologists. It manifestly is not in the whole encephalon, as certain portions of it may be irritated in the living animal without exciting convulsions. Parts of it, again, may be removed without preventing the remainder from exciting muscular contraction when irritated. In the experiments of M. Flourens, the cerebral lobes were taken away, yet the animals, when stimulated, were susceptible of motion; and, whenever the medulla oblongata was irritated, convulsions were produced. Its seat is not, therefore, in the whole encephalon. M. Rolando refers it to the cerebellum. He asserts, that on removing the cerebellum of living animals, without implicating any other part of the encephalon, they preserved their sensibility and consciousness, but were deprived of the power of motion. This occurred to a greater extent in proportion to the severity of the injury inflicted on the cerebellum. If the injury was slight, the loss of power was slight; and conversely. Impressed with the resemblance between the cerebellum of birds and the galvanic apparatus of the torpedo; and taking into consideration the lamellated structure of the cerebellum, which, according to him, resembles a voltaic pile; and

the results of his experiments, which showed, that the movements diminished in proportion to the injury done to the cerebellum, Rolando drew the inference, that this part of the encephalon is an electro-motive apparatus for the secretion of a fluid analogous to the galvanic. This fluid is, according to him, transmitted along the nerves to the muscles, and excites them to contraction. The parts of the encephalon concerned in volition would, in this view, regulate the quantity in which the motive fluid is secreted; and govern the motions; whilst the medulla oblongata, which, when alone irritated, always occasions convulsions, would put the encephalic extremity of the conducting nerves in direct or indirect communication with the locomotive apparatus.

This ingenious and simple theory is, however, far from being corroborated, by the fact, mentioned by M. Magendie,[1] that he is annually in the habit of exhibiting to his class animals deprived of cerebellum, which are capable of executing regular movements. For example, he has seen the hedgehog and Guinea-pig, deprived not only of brain but of cerebellum, rub the nose with its paw, when a bottle of strong acetic acid was held to it; and he remarks, that a single positive fact of the kind is worth all the negative facts that could be adduced. He farther observes, that there could be no doubt of the entire removal of the brain in his experiments. The experiments of Magendie are, however, equally adverse to the hypothesis of M. Flourens, that the cerebellum is the *regulator* or *balancer* of the movements. Some anatomical observations by Mr. Solly[2] would seem to show, that there is a direct communication between the motor tract of the spinal marrow and the cerebellum. The corpora pyramidalia have been generally supposed to be formed by the entire mass of the anterior or motor columns of the spinal cord, but Mr. Solly shows, that not more than one-half of the anterior column enters into the composition of these bodies; and that another portion, which he terms "antero-lateral column," when traced on each side in its progress upwards, is found to cross the cord below the corpora olivaria, forming, after mutual decussation, the surface of the corpora restiformia; and being ultimately continuous with the cerebellum.

Others, again, have estimated the encephalon to be the sole organ of volition, and have referred the nervous action, which produces the "locomotive influx," as it is termed, exclusively to the spinal marrow; and hence they have termed the spinal marrow, and the nerves issuing from it, the "*nervous system of locomotion.*" It is manifest, however, that the encephalon must participate with the medulla spinalis in this function; inasmuch as not only does direct irritation of several parts of the former excite convulsions, but we see them frequently as a consequence of disease of the encephalon; yet, as has been remarked, there is some reason for believing, that, in the upper classes of animals, an obscure volition may be exercised for a time, even when the encephalon is separated from the body. It need scarcely be said, that we

[1] Précis, &c., i. 340.

[2] Transactions of the Royal Society for 1836; and Solly on the Brain, Amer. edit., Phila., 1848.

are as ignorant of the character of this influx, as we are of that of the nervous phenomena in general.

The parts of the encephalon and spinal marrow, concerned in muscular motion, are very distinct from those that receive the impressions of external bodies. The function of sensibility is comprised in the medulla oblongata and in the posterior column of the spine, whilst the encephalic organs of muscular motion appear to be the corpora striata, the thalami nervorum opticorum, at their lower part; the crura cerebri; the pons Varolii; the peduncles of the cerebellum; the lateral parts of the medulla oblongata, and the anterior column of the medulla spinalis. This is proved by direct experiment, as will be shown presently; and, in addition to this, pathology furnishes us with numerous examples of their distinctness. In various cases of hemiplegia or palsy of one side of the body,—which is of encephalic origin,—we find motion almost lost; yet sensibility may be slightly or not at all affected; and, on the other hand, instances of loss of sensation have been met with, in which the power of voluntary motion has continued. Modern discoveries in the system of vertebral nerves exhibit how this may happen. A considerable space may exist between the roots of a nerve, one of which shall be destined for sensation, the other for motion; yet both may pass out enveloped in one sheath;—the same nervous cord thus conveying the two irradiations, if they may be so termed. According to Sir Charles Bell's system the spinal column is divided into three tracts; the anterior for motion; the posterior for sensibility; and the two are kept separate and united by the third—the column for respiration. The existence of the last column is now admitted by few.[1]

The experiments performed by the French physiologists especially,—for the purpose of discovering the precise parts of the encephalon concerned in muscular motion, have attracted great and absorbing interest. We wish it could be said, that the results have been such as to afford determinate notions on the subject. According to those of M. Flourens, the cerebral lobes preside over volition, and the medulla oblongata over the locomotive influx: to the latter organ he assigns, also, sensibility. We have seen, that the results of his experiments have been contested; and with them, of course, his deductions. The facts and arguments, already stated, throw doubts on all except the last proposition, which refers sensibility to the medulla oblongata; and even it is not restricted to that organ, or group of organs, whichsoever it may be considered.

MM. Foville and Pinel Grand-Champ[2] have affirmed that the cerebellum is the seat of sensibility. To this conclusion they were led by the remarks they had made, in the course of their practice, that the cases of paralysis of sensibility, which fell under their notice, succeeded more especially to morbid conditions of the encephalon. In this view they conceive themselves supported by the discovery of columns in the spinal marrow destined for particular functions; and, as the posterior column is found to be the column of sensibility, and the cerebellum seems to be formed from this column, they think it ought to be possessed of the same functions. M. Adelon[3] remarks, that

[1] See page 89. [2] Sur le Système Nerveux, Paris, 1820. [3] Op. citat., ii. 38.

Willis professed a similar notion, and that he considered the cerebral lobes to be the point of departure for the movements, and the cerebellum the seat of sensibility. In his first volume, however, he had cited more correctly the views of Willis. "Willis says positively," he remarks, "that the corpora striata are the seat of *perception;* the medullary mass of the brain, that of *memory* and *imagination;* the corpus callosum, that of *reflection;* and the cerebellum, the source of the *motive spirits.*" Willis, in truth, regarded the cerebellum as supplying animal spirits to the nerves of involuntary functions, as the heart, intestinal canal, &c. The opinions of Foville and Pinel Grand-Champ are, however, subverted by the experiments of Rolando, Flourens, and Magendie, which show, that sensation continues, notwithstanding serious injury to, and even entire removal of, the cerebellum.

By other physiologists, the two functions have been assigned respectively to the cineritious and medullary parts of the brain; some asserting, that the seat of sensibility is more especially in the latter, and the motive force in the former. According to Treviranus, the more medullary matter an animal has in its brain and spinal marrow, in proportion to the cineritious, the greater will be its sensibility. To this, however, M. Desmoulins[1] properly objects, that in many animals, the spinal marrow is composed exclusively of medullary matter [?]; and consequently they ought not only to be the most sensible of all, but to be wholly devoid of the power of motion. Others, again, as MM. Foville and Pinel Grand-Champ have reversed the matter; assigning sensibility to the cineritious substance, and motility to the medullary. From these conflicting opinions, it is obviously impossible to sift anything categorical; except that we are ignorant of the special seat of these functions. A part of the discrepancy, in the results, must be ascribed to organic differences in the animals which were the subjects of the experiments. This was strikingly exemplified in those instituted by M. Magendie, which have been cited. Similar contrariety exists in the experiments and hypotheses, regarding the particular parts of the encephalon, that are concerned in determinate movements of the body. The results of many of those are, indeed, so strange, that did they not rest on eminent authority they might be classed among the romantic.

It has been already remarked, that Rolando considered the cerebellum to be an electro-motive apparatus, producing the whole of the galvanic fluid necessary for the motions. M. Flourens, on the other hand, from similar experiments, independently performed, and without any knowledge of those of Rolando, affirmed it to be the regulator and balancer of the locomotive movements; and he asserted, that, when removed from an animal, it could neither maintain the erect attitude, nor execute any movement of locomotion; nor, although possessing all its sensations, could it fly from danger it saw menacing it. The same view has been advocated by M. Bouillaud, who has detailed eighteen experiments, in which he cauterized the cerebellum, and found that, in

[1] Anatomie des Systèmes Nerveux, &c., Paris, 1825.

all, the functions of equilibration and progression were disordered. The experiments of M. Magendie[1] on this subject, are pregnant with important novelty. We have already referred to those that concern the cerebral hemispheres and cerebellum as the encephalic organs of the general movements, in the mode suggested by MM. Rolando and Flourens, and others. M. Magendie affirms, in addition, "that there exist, in the brain, four spontaneous impulses or forces, which are situate at the extremity of two lines, cutting each other at right angles; the one impelling forwards; the second backwards; the third from right to left, causing the body to rotate; and the fourth from left to right, occasioning a similar movement of rotation." The first of these impulses he fixes in the cerebellum and medulla oblongata; the second in the corpora striata; and the third and fourth in each of the peduncles of the cerebellum.

1. *Forward Impulse.*—It has often been observed by those who have made experiments on the cerebellum, that injuries of it cause animals to recoil manifestly against their will. M. Magendie[2] asserts, that he has frequently seen them, when wounded in the cerebellum, make an attempt to advance, but be immediately compelled to run back; and he says that he kept a duck for eight days, the greater part of whose cerebellum he had removed, which did not move forwards during the whole of that time, except when placed on water. Pigeons, into whose cerebella he thrust pins, constantly walked and flew backwards, for more than a month afterwards. Hence, he concludes, that there exists, either in the cerebellum or medulla oblongata, a force of impulsion, which tends to cause animals to go forward. He thinks it not improbable, that this force exists in man; and states that Dr. Laurent, of Versailles, exhibited to him, and to the *Académie Royale de Médecine*, a young girl, who, in the attacks of a nervous disease, was obliged to recoil so rapidly, that she was incapable of avoiding bodies or pits behind her; and was, consequently, exposed to serious falls and bruises. This force, he affirms, exists only in the mammalia and birds;—certain fish and reptiles, on which he experimented, appearing to be unaffected by the entire loss of the cerebellum.

2. *Backward Impulse.*—M. Magendie found,[3] when the corpora striata were removed, that the animal darted forward with great rapidity; and, if stopped, still maintained the attitude of running. This was particularly remarked in young rabbits; the animals appearing to be impelled forward by an inward and irresistible power, and passing over obstacles without noticing them. These effects were not found to take place, unless the white, radiated part of the corpora striata was cut: if the gray was alone divided, no modification was produced in the movements. If only one of the corpora was removed, the rabbit remained master of its movements, directed them in different ways, and stopped when it chose; but, immediately after the removal of the other, all regulating power over the motions appeared to cease, and it was irresistibly impelled forwards. In the disease of the horse, called, by the French, *immobilité*, the animal is often capable of walking, trotting, and gallop-

[1] Op. citat., i. 345. [2] Précis, i. 341. [3] Op. cit., i. 337.

ing forward with rapidity; but he does not back; and frequently it is impracticable to arrest his motion forwards. M. Magendie[1] asserts, that he has opened several horses that died in this condition; and found, in all, a collection of fluid in the lateral ventricles, which had produced a morbid change on the surface of the corpora striata, and must have exerted a degree of compression on them.

Similar pathological cases occur in man. M. Magendie relates the case of a person, who became melancholic, and lost all power over his movements; continually executing the most irregular and fantastic antics; and frequently compelled to walk exclusively forwards or backwards until stopped by some obstacle. In this case, recovery occurred; and, accordingly, there was no opportunity for investigating the encephalic cause. M. Itard describes two cases, in which the patients were impelled, in paroxysms, to run straight forward, without the power of changing their course, even when a river or precipice was before them. A case is related by M. Piédagnel,[2] which is more to the purpose as an opportunity occurred for *post mortem* examination. The subject of it also was irresistibly impelled to constant motion. "At the time of the greatest stupor," says M. Piédagnel, "he suddenly arose; walked about in an agitated manner; made several turns in his chamber, and did not stop until fatigued. On another occasion, the room did not satisfy him; he went out, and walked as long as his strength would permit. He remained out about two hours, and was brought back on a litter." M. Piédagnel adds, "that he seemed impelled by an insurmountable force," which kept him in motion, until his powers failed him. On dissection, several tubercles were found in the right cerebral hemisphere, especially at its anterior part; and at the side of the corpora striata. These had produced much morbid alteration in that hemisphere; and had, at the same time, greatly pressed on the other. From these facts, M. Magendie infers it to be extremely probable, that, in the mammalia and in man, a force of impulsion always exists, which tends to impel backwards, and is, consequently, the antagonist to the force seated in the cerebellum.

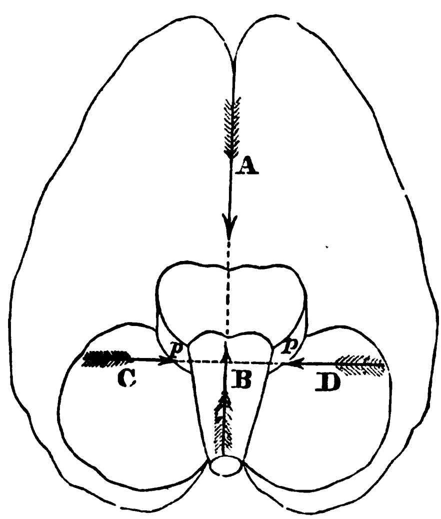
3. *Lateral Impulse.*—If the peduncles of the cerebellum—crura cerebelli—be divided in a living animal, it immediately begins to turn round, as if impelled by some considerable force. The rotation or circumgyration is made in the direction of the divided peduncle—M. Longet says, in the opposite direction—and, at times, with such rapidity, that the animal makes as many as sixty revolutions in a minute. The same kind of effect is produced by any vertical section of the cerebellum, which implicates from before to behind the whole substance of the medullary arch formed by that organ above the fourth ventricle; but the movement is more rapid, the nearer the section is to the origin of the peduncles; in other words to their point of junction with the pons Varolii. M. Magendie[3] affirms, that he has seen this movement continue eight days without stopping, and apparently without any suffering. When an impediment was placed in the way, the motion was arrested; and,

[1] Op. cit., i. 338.
[2] Magendie, Journal de Physiologie, tom. iii.; and Précis Elémentaire, i. 338.
[3] Précis, &c., i. 343.

under such circumstances, the animal frequently remained with its paws in the air, and ate in this attitude. What he conceives to have been one of his most singular experiments was,—the effect of the division of the cerebellum into two lateral and equal halves: the animal appeared to be alternately impelled to right and left, without retaining any fixed position: if he made a turn or two on one side, he soon changed his motion and made as many on the other. M. Serres[1]—who is well known as a writer on the comparative anatomy of the brain, and must have had unusual opportunities for observation at the Hospital *La Pitié* to which he was attached—gives the case of an apoplectic, who presented, amongst other symptoms, the singular phenomenon of turning round, like the animals in those experiments; and, on dissection, an apoplectic effusion was found in that part of the encephalon. On dividing the pons Varolii vertically, from before to behind, M. Magendie[2] found, that the same rotary movement was produced: when the section was to the left of the median line, the rotation was to the left, and conversely; but he could never succeed in making the section accurately on the median line. From these facts he concludes, that there are two forces, which are equilibrious by passing across the circle formed by the pons Varolii and cerebellum. To put this beyond all question, he cut one peduncle, when the animal immediately rolled in one direction; but on cutting the other or the one on the opposite side, the movement ceased, and the animal lost the power of keeping itself erect, and of walking.

From the results of all his experiments, M. Magendie infers, that an animal is a kind of automatic machine, wound up for the performance of certain motions, but incapable of producing any other. The figure of the base of the brain in the margin, will explain, more directly, the impulses described by this physiologist. The corpora striata are situate in each hemisphere, but their united impulses may be represented by the arrow A; the impulse seated in the cerebellum, by the arrow B; and those in each peduncle of the cerebellum, *p*, *p*, by the arrows C and D respectively. When the impulse backwards is from any cause destroyed, the animal is given up to the forward impulse, or that represented by the arrow B; and conversely. In like manner, the destruction of one lateral impulse leaves the other without an antagonist, and

Fig. 165.



Direction of Encephalic Impulses, according to Magendie.

[1] Magendie's Journ. de Physiol., iv. 405.

[2] Précis, &c., p. 344.

the animal moves in the direction of the arrow placed over the seat of the impulsion that remains. In a state of health, all these impulsions being nicely antagonized, they are subjected to the influence of volition; but in disease they may be so modified as to be entirely withdrawn from its control.

These four are not the only movements excited by particular injuries done to the nervous system. M. Magendie[1] states, that a circular movement to the right or left, similar to that of horses in a circus, was caused by the division of the medulla oblongata, to the outer side of the corpora pyramidalia anteriora. When the section was made on the right side, the animal turned, in this fashion, to the right; and to the left, if the section was made on that side.

Pathology has, likewise, indicated the brain as the seat of different bodily movements. Diseases of the encephalon have been found not only to cause irregular movements or convulsions, but, also, paralysis of a part of the body, leaving the rest untouched. Hence it has been concluded, that every motion of every part has its starting point in some portion of the brain. The ancients were well aware, that in cases of hemiplegia, the encephalic cause of the affection is found in the opposite hemisphere. Attempts have been made to decide upon the precise part of the encephalon in which the decussation takes place. Many have conceived it to be in the commissures; but the greater number, perhaps, have referred it to the corpora pyramidalia. These, the researches of Gall and Spurzheim[2] and others, had pointed out as decussating at the anterior surface of the marrow, and as being apparently continuous with the radiated fibres of the corpora striata; and an opinion has prevailed, that the paralysis is of the same side as the encephalic affection, or of the opposite, according as the affected part of the brain is a continuation of fasciculi, which do not decussate—of the corpora olivaria, for example—or of the corpora pyramidalia, which do. M. Serres,[3] however, affirms, that affections of the cerebellum, pons Varolii, and tubercula quadrigemina, exert their effects upon the opposite side of the body, and he supports his statement by pathological cases and direct experiment. M. Magendie[4] divided one pyramid from the fourth ventricle; yet no sensible effect was produced on the movements; certainly, there was no paralysis, either of the affected or opposite side: he then divided both pyramids about the middle, and no apparent derangement occurred in the motions—a slight difficulty in progression being alone observable. The section of the posterior pyramids was equally devoid of perceptible influence on the general movements; and to cause paralysis of one half the body, it was necessary to divide the half of the medulla oblongata, when the corresponding side became,—not immovable, for it was affected by irregular movements; and not insensible, for the animal moved its limbs when they were pinched,—but incapable of executing the determinations of the will.

These views are not exactly in accordance with the general idea,

[1] Précis, &c., p. 345.
[2] Recherches sur le Système Nerveux, &c., sect. vi., Paris, 1809.
[3] Anatomie Comparée du Cerveau, Paris, 1824.
[4] Op. cit.

that disease, confined to one hemisphere of the brain, or cerebellum, and to one side of the mesial plane in the tuber annulare, constantly affects the opposite side; whilst disease, confined to one of the lateral columns of the medulla oblongata and medulla spinalis, affects the corresponding side of the muscular system;—the encephalon having a crossed,—the medulla a direct effect.[1] The crossing of the fibres at the anterior surface of the marrow would not, however, account for the loss of sensation in hemiplegia. Mr. Hilton[2] has examined carefully the continuation upwards of the anterior and posterior columns of the spinal marrow into the medulla oblongata, and found, that the decussation at the upper part of the marrow belongs in part to the column for motion, and in part to the column for sensation; and farther, that the decussation is only partial with respect to either of the columns.

The result of the examination of morbid cases has induced some physiologists to proceed still farther in their location of the encephalic organs of muscular motion; and to attempt an explanation of paraplegia, or cases in which one half the body, under the transverse bisection, is paralyzed. MM. Serres, Foville, and Pinel Grand-Champ assert, that the anterior radiated portion of the corpora striata presides over the movements of the lower limbs; and the optic thalami over those of the upper; and that according as the extravasation of blood, in a case of apoplexy, occurs in one of these parts, or in all, the paralysis is confined to the lower or to the upper limbs, or extends over the whole body. In 1768, M. Saucerotte[3] presented a prize memoir to the *Académie Royale de Chirurgie*, of Paris, in which a similar view was expressed. He had concluded, from experiments, that affections of the anterior parts of the encephalon paralyse the lower limbs, whilst those of the posterior parts paralyse the upper. M. Chopart,—in a prize essay, crowned in 1769, and contained in the same volume with the last—refers to the results of experiments by M. Petit, of Namur, which appeared to show, that paralysis of the opposite half of the body was not induced by injury of the cerebral hemisphere, unless the corpora striata were cut or removed. The experiments by Saucerotte were repeated by M. Foville, and are detailed in a memoir, crowned by the *Académie Royale de Médecine*, of Paris, in 1826. They were attended with like results. In cats and rabbits, he cauterized, in some, the anterior part of the encephalon; in others, the posterior: in every one of the former, paralysis of the posterior, and in the latter, of the anterior extremities succeeded. Having in one animal mutilated the whole of the right hemisphere, and only the anterior part of the left, he found that the animal was paralysed in the hinder extremities, and in the paw of the left fore-leg; but that the paw of the right remained active.[4]

[1] Lectures on the Nervous System and its Diseases, by Marshall Hall, M.D., &c., Lond., 1836, p. 34, or Amer. edit., Philad., 1836.

[2] Proceedings of the Royal Society, No. 34, for 1837–8; also, Solly on the Brain, p. 145, Lond., 1836; and Dr. John Reid, Edinb. Med. and Surg. Journ., Jan., 1841, p. 12.

[3] Prix de l'Académie Royale de Chirurgie, vol. iv. p. 373, Paris, 1819.

[4] Adelon, Physiologie de l'Homme, edit. cit., ii. 44.

Lastly, the motions of the tongue or of articulation are sometimes alone affected in apoplexy. The seat of this variety of muscular motion has been attempted to be deduced from pathological facts. M. Foville places it in the cornu ammonis and temporal lobe; and M. Bouillaud[1] in the anterior lobe of the brain, in the medullary substance, —the cineritious being concerned, he conceives, in the intellectual part of speech.

It is sufficiently obvious, from the whole of the preceding detail, that the mind must still remain in doubt, regarding the precise part of the encephalon engaged in the functions of muscular motion. The experiments of M. Magendie are, perhaps, more than any others, entitled to consideration. They appear to have been instituted without any particular bias; to subserve no particular theory; and are supported by pathological facts furnished by others. He is, withal, a practised experimenter, and one to whom physiology has been largely indebted. His vivisections have been more numerous, perhaps, than those of any other individual. His investigations, however, on this subject clearly show, that owing to the different morphology of animals, we cannot draw as extensive analogical deductions from comparative anatomy and physiology as might be anticipated. The greatest source of discrepancy, indeed, between his experiments and those of MM. Rolando and Flourens, appears to have been the employment of different animals. Where the same animals were the subjects of the vivisections, the results were in accordance. The experiments demand careful repetition, accompanied by watchful and assiduous observation of pathological phenomena; and, until this is effected, we can, perhaps, scarcely feel justified in deducing, from all these experiments and investigations, more than the general propositions regarding the influence of the cerebro-spinal axis on muscular motion, which we have enunciated. It has been already shown, however, that strong evidence may be adduced in favour of the view of M. Flourens, that the cerebellum is the regulator or co-ordinator of the muscular movements,[2] and it is the one now embraced by the generality of physiologists; although it must be admitted, with M. Longet,[3] that "the precise determination of the uses of the cerebellum is one of the most embarrassing problems in physiology."

The nerves, it has been shown, are the agents for conducting the locomotive influence to the muscles. At one time, it was universally believed, that the same nerve conveys both sensation and volition; but the pathological cases, that not unfrequently occurred, in which either sensation or voluntary motion was lost, without the other being necessarily implicated; and, of late years, the beautiful additions to our knowledge of the spinal nerves, for which we are mainly indebted to Sir Charles Bell,[4] and M. Magendie,[5] have satisfied the most sceptical, that

[1] Magendie's Journal de Physiologie, tom. x.; also, Belhomme, Archiv. Général. de Médecine, Mai, 1845.

[2] Longet, Anatomie et Physiologie du Système Nerveux, i. 703, Paris, 1842.

[3] Traité de Physiologie, ii. 272, Paris, 1850.

[4] The Nervous System, &c., 3d edit., Lond., 1837, and Narrative of the Discoveries of Sir Charles Bell in the Nervous System, by A. Shaw, London, 1839.

[5] Précis Elémentaire, &c., 2de édit., i. 216.

there are separate nerves for the two functions, although they may be enveloped in the same neurilemma or nervous sheath; and may constitute one nervous cord. We have more than once asserted, that the posterior part of the spinal marrow, with the nerves proceeding from it, has been considered to be chiefly concerned in the function of sensibility; and the anterior column, and the nerves connected with it, to be inservient to muscular motion; whilst a third intervening column, in the opinion of Sir Charles Bell, is the source of all the respiratory nerves, and of the various movements connected with respiration and expression. It is proper, here again, to observe, that although these two distinguished physiologists agree in their assignment of function to the anterior and posterior columns of the spinal marrow, Bellingeri[1] has deduced very different inferences from like experiments. He asserts, that having divided, on living animals, either the anterior roots of the spinal nerves, and the anterior column of the medulla spinalis—or the posterior roots of these nerves, and the posterior column of the marrow, he did not occasion, in the former case, paralysis of motion, and in the latter, loss of sensation; but only, in the one, the loss of all movements of flexion; and in the other, of those of extension. In his view, the brain and its prolongations,—crura cerebri, corpora pyramidalia, anterior column of the spinal marrow, and the nerves connected with it, preside over the movements of flexion; and, on the contrary, the cerebellum and its extensions, as the posterior column of the medulla spinalis, and the nerves connected with it, preside over those of extension: he infers, in other words, that there is an *antagonism* between these sets of nerves. The *primâ facie* evidence is against the accuracy of Bellingeri's experiments. The weight of authority in opposition to him is, in the first place, preponderant; and in the second place, it seems highly improbable, that distinct nerves should be employed for the same kind of muscular action. Moreover, in experiments on the frog, Professor Müller established the correctness of the views of Bell. It seems, that the different physiologists, who engaged in the inquiry before he did, employed warm-blooded animals in their experiments, and he imagines, that the pain, resulting from the necessarily extensive wounds, may have had such an effect on the nervous system as to modify, and perhaps even counteract, the results. Müller employed the frog, whose sensibility is less acute, and tenacity of life greater. If the spinal marrow of this animal be exposed, and the posterior roots of the nerves of the lower extremities be cut, not the least motion is perceptible when the divided roots are touched by mechanical means, or galvanism. But if the anterior roots be touched, the most active movements are instantly observed. These experiments, Müller[2] remarks, are so readily made, and the evidence they afford is so palpable, that they leave no doubt as to the correctness of the views of Sir Charles Bell.

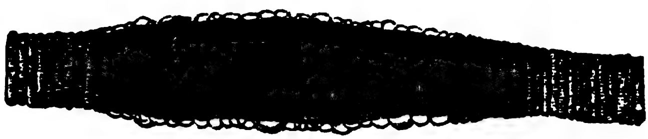
[1] Exper. Physiol. in Med. Spinal. August, Taurin., 1825; Ragionamenti, Sperienze, &c., comprovanti l'Antagonismo Nervoso, &c. Torino, 1833; and an Analysis of the same, in Edinb. Med. and Surg. Journ., Jan., 1835, p. 160.

[2] Elements of Physiology, by Baly, p. 644, Lond., 1838.

Experiments, by M. Magendie, and by Dr. Kronenberg,[1] of Moscow, have shown, that a portion of the fibres of the sensitive roots extends to the point of union between them and the anterior roots, and is reflected to the anterior column of the spinal marrow;—the return or reflection of the fibres taking place near the junction of the two roots. This arrangement of the fibres accounts for the fact, often noticed by physiologists, that some degree of sensibility appears to be manifested, in experiments on animals, when the motor roots of the nerves are irritated. The sensibility of the portio dura, a motor nerve, has been long known, and properly ascribed to its receiving filaments of the fifth pair. Motions can be excited by irritating the posterior root, which are owing to its connexion with the spinal cord. This irritation does not act immediately upon the muscles through the trunk of the nerve, which the posterior root contributes to form; but it excites a motor impulse in the spinal cord, which is propagated through the anterior roots to the periphery of the system.

In the ordinary case of the action of a voluntary striped or striated muscle, the nervous influence, emanating from some part of the cerebro-spinal axis, under the guidance of volition, proceeds along the nerves with the rapidity of lightning, and excites the muscle to contraction. The muscle, which was before smooth, becomes rugous; the belly more tumid; the ends approximate, and the whole organ is rendered thicker, firmer, and shorter. The researches of Mr. Bowman[2] have shown, that in the state of contraction the transverse striæ, before described as existing in each fibre, approach each other; whilst its diameter is increased; hence the solid parts are more closely approximated, and the fluid which previously existed between them is pressed out so as to form bullæ in the sarcolemma, as represented in Fig. 166, from Mr. Bowman. The

Fig. 166.



Muscular Fibre of Dytiscus in contraction. (Bowman.)

marginal representations, Fig. 167, of the muscular fibre of the skate, at rest and in contraction, are also from Mr. Bowman. It is proper to remark, however, that these representations are of muscular fibres when in an unnatural condition,—separated, that is, from the rest of the economy, and it cannot be considered established, that contraction excited by the agency of the nerves is accomplished in precisely the same manner.

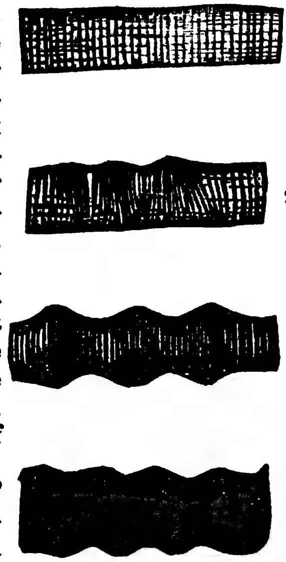
With regard to the degree of contraction or shortening, which a muscle experiences, some difference of sentiment has prevailed. Ber-

[1] Müller's Archiv., Heft v. 1839.

[2] Art. Muscular Motion, in Cyclop. of Anat. and Physiol., Part xxiv. p. 525, London, July, 1842; and Philosophical Transactions for 1840–1841.

nouilli and Keill[1] estimated it at one-third of the length; and Dumas[2] carried it still higher. It must, of course, be proportionate to the length of the fibres,—being greater, the longer the fibres. It has, also, been a subject of experiment and speculation, whether the bulk and the specific gravity of a muscle be augmented during contraction. Borelli[3] and Sir Anthony Carlisle[4] affirm, that its bulk is increased. In the experiments of the latter, the arm was immersed in a jar of water, with which a barometrical tube was connected; and when the muscles were made to contract strongly, the level of the water in the tube was raised. Glisson, however, from the same experiment, deduced opposite conclusions; Swammerdam and Ermann[5] appear to be of their opinion; but Sir Gilbert Blane,[6] Mr. Mayo,[7] Barzellotti,[8] MM. Dumas and Prévost,[9] and Valentin,[10] during the most careful experiments could see no variation in the level of the fluid; and, consequently, do not believe, that the size of a muscle is modified by contraction. Sir Gilbert enclosed a living eel in a glass vessel filled with water, the neck of which was drawn out into a fine tube; he then, by means of a wire introduced into the vessel, irritated the tail of the animal, so as to excite strong contraction, during which he noticed, that the water in the vessel remained stationary. He, likewise, compared the two sides of a fish, one of which had been crimped, and thus brought into a state of strong contraction;—the other left in its natural condition: their specific gravity was the same. The experiment of Barzellotti was the following. He suspended, in a glass vessel, the posterior half of a frog; filled the jar with water, and closed it with a stopper, traversed by a narrow, graduated tube. The muscle was then made to contract by means of galvanism, but in no case was the level of the liquid in the tube changed. It may, then, be concluded, that the bulk of a muscle is not much, if at all, greater when contracted than when relaxed. Professor E. Weber, who repeated the experiments of Ermann, detected an increase of bulk, but it was exceedingly small.[11]

Fig. 167.



Muscular Fibre of Skate.

In a state of rest (1), and in three different stages of contraction (2, 3, 4). (Bowman.)

[1] Tentamina-Medico-Physica, Lond., 1718.
[2] Principes de Physiologie, &c., 2de édit., Paris, 1806.
[3] De Motu Animalium, addit. J. Bernouillii, Medit. Mathem. Muscul., L. B. 1710.
[4] Philos. Transact. for 1805, pp. 22, 23.
[5] Gilbert's Annalen, p. 40, 1812.
[6] A Lecture on Muscular Motion, &c., Lond., 1778; and Select Dissertations, &c., p. 239.
[7] Anatomical and Physiological Commentaries, i. 12; and Outlines of Human Physiology, 3d edit., p. 35, Lond., 1833.
[8] Esame di alcune moderne Teorie intorno alla Causa prossima della Contrazione moscolare, Siena, 1796.
[9] Op. citat., and Magendie, Précis, &c., i. 222.
[10] Lehrbuch der Physiologie des Menschen, s. 42, Braunschweig, 1844; and Grundriss der Physiologie, s. 218, Braunschweig, 1846.
[11] Art. Muskelbewegung, in Wagner's Handwörterbuch der Physiologie, 15te Lieferung, s. 52 und 121, Braunschweig, 1846.

rial blood; others to a union of the particles of the muscular fibre with the nervous fluid; and others, to the disengagement of an elastic gas, primitively contained in the blood, and separated from it by the nervous spirits. It would, however, be unprofitable, as well as uninteresting, to repeat the different absurdities of this period—so prolific in physical obscurities. Medicine has generally kept pace with physics, and where the latter science has been dark and enigmatical, the former has been so likewise. In physiology, this is especially apparent; most of the natural philosophers of eminence having applied their doctrines in physics to the explanation of the different functions of the human frame. Newton, Leibnitz, and Des Cartes, were all speculative physiologists. The discovery of electricity gave occasion to its application to the topic in question; and it was imagined, that the fibres of the muscle might be disposed in such a manner as to form a kind of battery, capable of producing contraction by its explosions; and after the discovery of galvanic electricity, Valli[1] attempted to explain muscular contraction, by supposing that the muscles have an arrangement similar to that of the galvanic pile. Haller[2] endeavoured to resolve the problem by his celebrated doctrine of *irritability*, which will engage attention hereafter. He conceived, that the muscles possess, what he calls, a *vis insita;* and that their contraction is owing to the action of this force, excited by a stimulus, which stimulus is the nervous influx directed by volition. This, although a true doctrine we think, sheds no new light on the mysterious process. It is, in fact, cutting the Gordian knot. We should still have to explain the precise mode of action of the vis insita:[3] but that it is not in any way derived from the nervous system will be shown when treating of LIFE.

The hypothesis of Prochaska[4] is entirely futile. He gratuitously presumes, that minute ramifications of arteries are every where connected with the ultimate muscular filaments, twining around them, and crossing them in all directions. When these vessels are rendered turgid by an influx of blood,—by passing among the filaments, they must, he conceives, bend the latter into a serpentine shape, and thus diminish their length, and that of the muscle likewise. Sir Gilbert Blane,[5] again, throws out a conjecture—deduced from experiments, in which he found that the actual bulk of a muscle is not changed during contraction, but that it gains in thickness exactly what it loses in length;—that this may be owing to the muscle being composed of particles of an oblong shape; and that when the muscle is contracted, the long diameter of the particle is removed from a perpendicular to a transverse direction. But the same objection applies to this as to other hypotheses on the subject; that it is entirely gratuitous,—resting on no histological observation whatever.

Two views have been, perhaps, the most prevalent; one which considers muscular contraction to be a kind of combustion; another that it

1 Experiments in Animal Electricity, Lond., 1793.
2 Element. Physiol., xi. 214; and Oper. Minor., tom. i.
3 M. Hall, art. Irritability, Cyclop. of Anat. and Physiol., July, 1840.
4 De Carne Musculari, § ii., Vienn., 1778.
5 Op. citat.

is produced by electricity. The former, which was originally propounded by Girtanner,[1] and zealously embraced by Dr. Beddoes, who was more celebrated for his enthusiasm than for the solidity of his opinions, has now few supporters. This hypothesis supposes, that muscular contraction depends upon the combustion of the combustible elements of the muscle, hydrogen and carbon, by the oxygen of the arterial blood; the combustion being produced by the nervous influx, which acts in the manner of an electric spark;—at least, such is the view adopted by M. Richerand,[2] one of the most fanciful of physiological speculators. Of course, we have neither direct nor analogical evidence of any such combustion, which, if it existed at all, ought to be sufficient, in a short space of time, to entirely consume the organs that furnish the elements. The idea is as unfounded as numerous others that have been entertained, and is worthy only of particular notice, from its being professed in one of the well-known works on physiological science.

The second hypothesis refers muscular contraction to electricity. Attention has been already directed to the electroid or galvanoid character of the nervous agency; and we have some striking examples on record of the analogous effects produced by the physical and the vital fluid on the phenomena under consideration. It has been long known, that when nerves and muscles are exposed in a living animal, and brought into contact, contractions or convulsions occur in the latter. Galvani[3] was the first to point this out. He decapitated a living frog; removed the fore-paws, and quickly skinned it. The spine was divided, so as to leave the spinal marrow communicating only with the hinder extremities by means of the lumbar nerves. He then took, in one hand, one of the thighs of the animal, and the vertebral column in the other, and bent the limb until the crural muscles touched the lumbar nerves. At the moment of contact the muscles were strongly convulsed. The experiment was repeated by Volta,[4] Aldini,[5] Pfaff,[6] Humboldt,[7] and others; and with like results. Aldini[8] caused convulsions in the muscles by the contact of those organs with nerves, not only in the same frog, but in two different frogs. He adds, that he remarked them when he put the nerves of a frog in connexion with the muscular flesh of an ox recently killed. Humboldt made numerous experiments of this kind on frogs, and found convulsions supervene when he placed upon a dry plate of glass a posterior extremity whose crural nerves had been exposed, and touched the nerves and muscles with a piece of raw muscular flesh, insulated at the extremity of a stick of sealing-wax. Convulsions likewise occurred, when, instead of one piece of flesh, he used three different pieces to form the chain, one of which touched the nerve; the other the thigh, and the third the two others. The experiments were repeated by Ritter with similar results; but they were

[1] Journal de Physique, xxxvii. 139.
[2] Elements of Physiology, § 163.
[3] Mem. sull' Elettricita Animale, Bologn., 1797.
[4] Memoria sull' Elettricita Animale, 1782.
[5] Essai Théoretique et Expériment. sur le Galvanisme, Paris, 1804.
[6] Ueber thierische Electricität und Reizbarkeit, Leipz., 1795.
[7] Versuche über die gereizte Muskel und Nervenfaser, Posen und Berlin, 1797.
[8] Traité complet de Physiologie de l'Homme, par Tiedemann, traduit par Jourdan, p. 559, Paris, 1837.

only found to succeed, when the frogs were in full vital activity,—especially in spring, after pairing; when the animal was of sufficient size, and its preparation for the experiment had been rapidly effected.

From all these experiments it might be inferred, that parts of an animal may form galvanic chains, and produce a galvanic effect, which, independently of any mechanical excitation, may give rise to the contraction of muscles. This excitation of electricity in chains of animal parts, M. Tiedemann thinks, ought not to be esteemed a vital act. Its effects only—the contractions excited in the muscles—are dependent on the vital condition of the muscles and nerves. He considers, that electricity, excited in chains of heterogeneous animal parts, may be modified and augmented by the organic or living forces; and that, moreover, in certain animals, organs exist, the arrangement of which is such as to excite electricity during their vital action as in the different kinds of electrical fishes; but in some experiments, instituted by M. Edwards,[1] the effects above referred to were produced by touching a denuded nerve with a slender rod of silver, copper, zinc, lead, iron, gold, tin, or platinum, and drawing it along the nerve for the space of from a quarter to a third of an inch. He took care to employ metals of the greatest purity, as they were furnished him by the assayers of the mint. But it was not even necessary that the rod should be metallic: he succeeded with glass or horn. All metals, however, did not produce equally vigorous contractions. Iron and zinc were far less effective than the others; but no accurate scale could be formed of their respective powers.

Much difference is found to exist, when electricity is employed, according as the nerve is insulated or not; for as the muscular fibre is a good conductor of electricity, if the nerve be not insulated, the electricity is communicated to both nerve and muscle, and its effect is consequently diminished. It became, therefore, interesting to M. Edwards to discover, whether any difference would be observable, when one metal only was used, whether the nerve was insulated or not. In the experiments above referred to, the nerve was insulated by passing a strip of oiled silk beneath it. A comparison was now instituted between an animal thus prepared, and another whose nerves instead of being insulated, rested on the subjacent flesh. He made use of small rods, with which he easily excited contractions when he drew them from above to below along the denuded portion of nerve that was supported by the oiled silk; but he was unable to cause them when he passed the rod along the nerve of the other animal which was not insulated. His experiments were then made on two nerves of the same animal; and he found that after having vainly attempted to produce contractions by the contact of a nerve resting upon muscle, they could still be induced if the oiled silk were had recourse to; and he was able to command their alternate appearance and disappearance by using a non-conductor or a conductor for the support of the nerve. Somewhat surprised at these results, M. Edwards was stimulated to the investigation,—whether

[1] Appendix to Edwards on the Influence of Physical Agents on Life,—Hodgkin and Fisher's translation, Lond., 1832.

some degree of contraction might not be excited by touching the uninsulated nerve, and having remarked, that contractions were most constantly produced in the insulated nerve by a quick and light touch, he adopted this method on an animal whose nerve was not insulated, and frequently obtained slight contractions. All his experiments on this subject seemed to prove, that, *cæteris paribus*, muscular contractions, produced by the contact of a solid body with a nerve, are much less considerable, or even wholly wanting, when the nerve, in place of being insulated, is in communication with a good conductor; and it would seem to follow, as a legitimate conclusion, that these contractions are dependent on electricity; facts, which it is well to bear in mind, in all experiments on animals where feeble electrical influences are employed.[1]

Galvanic electricity, it will be seen hereafter, is one of the great tests of muscular irritability, and is capable of occasioning contractions for some time after the death of the animal, as well as of maintaining, for a time, many of the phenomena peculiar to life. This is the reason why muscular contraction, excited by this nervous, electroid fluid, has been regarded as an electrical phenomenon. Much discrepancy has, however, arisen amongst the partisans of this opinion regarding its *modus operandi*. Rolando, we have seen, assimilates the cerebellum to an electro-motive apparatus, which furnishes the fluid that excites the muscles to contraction. Some have compared the spinal column to a voltaic pile, and have supposed the contraction of a muscle to be owing to an electric or galvanic shock. The views of MM. Dumas and Prévost[2] are amongst the most striking. By a microscope, magnifying ten or twelve diameters, they first of all examined the manner in which the nerves are arranged in a muscle; and found, as has been already observed, that their ramifications always enter the muscle in a direction perpendicular to its fibres. They satisfied themselves, that none of the nerves really terminate in the muscle; but that the final ramifications embrace the fibres like a noose, and return to the trunk that furnishes them, or to one in its vicinity,—the nerve setting out from the anterior column of the spinal marrow, and returning to the posterior. On farther examining the muscles at the time of their contraction, the parallel fibres composing them were found, under the microscope, to bend in a zigzag manner, and to exhibit a number of regular undulations; such flexions forming angles, which varied according to the degree of contraction, but were never under fifty degrees. The flexions, too, always occurred at the same parts of the fibre, and to them the shortening of the muscle was owing, as MM. Dumas and Prévost proved by calculating the angles. The angular points were always found to correspond to the parts where the small nervous filaments enter or pass from the muscles. (See page 371.) They therefore believed, that these filaments, by their approximation, induce contraction of the muscular fibre; and this approximation they ascribed to a galvanic current running through them; which, as the fibres are parallel and in proximity, they thought, ought to cause them to attract each other, according to the law

[1] Coldstream, art. Animal Electricity, in Cyclop. Anat. and Physiol., P. ix. p. 93, Jan., 1837; and J. Müller, Elements of Physiology, by Baly, p. 261, London, 1838.

[2] Journal de Physiologie, tom. iii. 301; and Magendie, Précis, i. 220.

laid down by M. Ampère, that two currents attract each other when they move in the same direction. The living muscles are, consequently, regarded by them as galvanometers, and galvanometers of an extremely sensible kind, on account of the very minute distance and tenuity of the nervous filaments. They moreover affirm, that, by anatomical arrangement, the nerve is fixed in the muscle in the very position required for the proper performance of its function; and they esteem the fatty matter, which envelopes the nervous fibres, and which was discovered by M. Vauquelin, as a means of insulation for preventing the electric fluid from passing from one fibre to another.

Soon after hearing of M. Ampère's discovery of the attraction of electrical currents, it occurred to Dr. Roget,[1] that it might be possible to render the attraction between the successive and parallel turns of heliacal or spiral wires very sensible, if the wires were sufficiently flexible and elastic; and, with the assistance of Dr. Faraday, his conjecture was put to the test of experiment in the laboratory of the Royal Institution of London. A slender harpsichord-wire, bent into a helix, being placed in the voltaic circuit, instantly shortened itself whenever the electric stream was sent through it; but recovered its former dimensions the moment the current was intermitted. From this experiment it was supposed, that possibly some analogy might hereafter be found to exist between the phenomenon and the contraction of muscular fibre.

The views of MM. Dumas and Prévost were altogether denied by M. Raspail,[2] on the ground, that it is impossible to distinguish, by the best microscope, the ultimate muscular fibre from the small nervous fibrils by which those gentlemen consider them to be surrounded loopwise. He farther affirmed, that the zigzag form is the necessary result of the method in which they performed their experiments, and is produced by the muscular fibre adhering to the glass on which it was placed. His own idea, founded on numerous observations, is, that the contraction of the fibre in length is always occasioned by its extension in breadth under the influence of the vital principle. Independently, however, of M. Raspail's objection, the circumstance, that, in this mode of viewing the subject, the muscle itself is passive, and the nerve alone active, is a stumbling-block in the way of the views of MM. Dumas and Prévost, and of Dr. Roget. It is proper, too, to remark, that M. Person[3] was unable to detect any longitudinal galvanic currents in the nerves by the most sensible galvanometer; and that other stimuli besides galvanism are capable of exciting the muscular fibre to contraction. This we daily see in experiments on the frog, by dropping salt on the denuded muscle. Prof. Müller[4] hence infers, that a nerve of motion, during life, and whilst its excitability or irritability continues, is so circumstanced, that whatever suddenly changes the relative condition of its molecules excites a contraction at the remote end of the muscle, and

[1] Electro-Magnetism, p. 59, in 2d vol. of Nat. Philosophy, Library of Useful Knowledge, London, 1832.

[2] Chimie Organique, p. 212, Paris. 1833.

[3] Journal de Physiologie, tom. x. Paris, 1830.

[4] Art. Electricität (thierische) in Encyclopäd. Wörterb. der Medicin. Wissensch., x. 545, Berlin, 1834.

that electrical, chemical, and mechanical irritants are, in this respect, similarly situate.

Interesting electro-physiological researches have been made by Professor Matteucci of Pisa, from which he has deduced the following results. *First.* Muscle is a better conductor of electricity than nerve; and nerve conducts better than brain. The conducting power of muscle may be taken as four times greater than that of brain or nerve. *Secondly.* In the muscles of living animals, as well as of those recently killed, an electric current exists, which is directed from the interior of each muscle to its surface. The duration of this muscular current corresponds with that of contractility; in cold-blooded animals, therefore, it is greatest: in mammalia and birds very brief. Temperature has a considerable influence on the intensity of the current,—a small amount of electricity being developed in a cold medium; a larger one when the medium is moderately warm. Any circumstance that enfeebles the frogs (the animals experimented on) and deranges their general nutrition, diminishes the power of the muscles to generate electricity, as it likewise impairs the contractile force. The muscular current appears to be quite independent of the nervous system. It is uninfluenced by narcotic poisons in moderate doses, but is destroyed by large doses, such as would kill the animal. The developement of this muscular current seems evidently to depend on the chemical action constantly taking place as an effect of the changes accompanying nutrition. *Thirdly.* In frogs an electric current exists, which is distinct from the muscular current. It proceeds from the feet to the head, and is peculiar to batrachian reptiles. *Fourthly.* Singular results are obtained by applying electricity in various ways to nerves. On making experiments on the sciatic nerves of rabbits, he found that on *closing* the circuit of the *direct* electric current, or the current passing from the brain to the nerves, contractions in the muscles of the posterior limbs were produced; whilst *opening* this circuit was followed by marked signs of pain, with contraction of the muscles of the back, and feeble contractions of the posterior limbs. On *closing* the circuit of the *inverse* current, or that directed from the nerves to the brain, signs of pain, contractions of the muscles of the back, and feeble contractions of the posterior limbs were produced. On *opening* it, contractions of the posterior limbs followed.[1]

With regard to the hypotheses which ascribe muscular contractility to the chemical composition of the fibre, and that which maintains, that the property is dependent upon the mechanical structure of the fibre, they are undeserving of citation, notwithstanding the respectability of the individuals who have written and experimented on the subject. They merely seem to show, that here, as in every case, a certain chemical and mechanical constitution is necessary, in order that the vital operation, peculiar to the part, may be accomplished.

But not only is it necessary, that the muscle shall possess a proper

[1] For an account of Matteucci's researches, see Todd and Bowman, Physiological Anatomy and Physiology of Man, vol. i., Lond., 1845, and, especially, Matteucci, Lectures on the Physical Phenomena of Living Beings, by Pereira, Amer. edit., pp. 176 and 224, Philad., 1848.

physical organization, it must, likewise, be endowed with a property essentially vital; in other words, with *irritability* or *contractility*. The cause of the ordinary contraction of muscles is, doubtless, the nervous influx; but if we materially alter the condition of the muscle, although the nervous influx may be properly transmitted to it, there will be no contraction. This applies to the living animal; but not apparently to the dead; for Valentin[1] found, that after tying the femoral artery or vein, or dividing the sciatic nerve in frogs, the full strength of the muscle remained unaltered for several days,—in one case for twelve. We moreover find, that after a muscle has acted for some time, it becomes fatigued, notwithstanding volition may regularly direct the nervous influx to it; and that it requires repose, before it is again capable of executing its functions.

In the upper classes of animals, contractility remains for some time after dissolution; in the lower, especially in the amphibia, the period during which it is evinced on the application of appropriate stimuli is much greater. From experiments on the bodies of executed criminals, M. Nysten found that irritability ceased in the following order of parts. The left ventricle of the heart first; the intestinal canal at the end of forty-five or fifty-five minutes; the urinary bladder at nearly the same time; the right ventricle after the lapse of an hour; the œsophagus at the end of an hour and a half; the iris a quarter of an hour later; the muscles of animal life somewhat later; and lastly, the auricles of the heart, especially the right, which, in one instance, under the influence of galvanism, contracted sixteen and a half hours after death. These results are singular; and the experiments merit repetition. It is, indeed, strange, that muscles of organic life, apparently circumstanced so much alike, should vary so greatly in the length of time during which they retain their irritability.

One of the most interesting of the many experiments that have been made on the bodies of criminals recently deceased, for the purpose of exhibiting the effects of galvanism on muscular irritability, is detailed by Dr. Ure.[2] The subject was a murderer, named Clydesdale; a middle-sized athletic man, about thirty years of age. He was suspended from the gallows nearly an hour, and made no convulsive struggle after he dropped. He was taken to the theatre of the Glasgow University about ten minutes after he was cut down. His face had a perfectly natural aspect, being neither livid nor tumefied; and there was no dislocation of the neck. In the first experiment, a large incision was made into the nape of the neck, close below the occiput, and the spinal marrow was brought into view. A considerable incision was made, at the same time, into the left hip, through the glutæus maximus muscle, so as to expose the sciatic nerve;[3] and a small cut was made in the heel; from

[1] Lehrbuch der Physiologie des Menschen, ii. 176–92, Braunschweig, 1844.

[2] Art. Galvanism, in Dict. of Chemistry, Hare and Bache's Amer. edit., Philad., 1821.

[3] It is not indispensable, in these experiments, to expose the nerve. The author has long known, that, in the case of the frog, it is needless; and, in his experiments, he has been in the habit of acting under this knowledge. The experiments made on three criminals,—two of whom were executed at Philadelphia, and the third at Lancaster, Pennsylvania—showed, indeed, that the effect was even greater when the nerves were not exposed. It was found, too, to be more marked when the current was transmitted from the peripheral extremity of

neither of which any blood flowed. A pointed rod, connected with one end of a galvanic battery, of two hundred and seventy pairs of four-inch plates, was now placed in contact with the spinal marrow, whilst another rod, connected with the other end, was applied to the sciatic nerve. Every muscle of the body was immediately agitated with convulsive movements, resembling a violent shuddering from cold. The left side was most powerfully convulsed at each renewal of the electric contact. On removing the second rod from the hip to the heel, the knee being previously bent, the leg was thrown out with such violence as nearly to overturn one of the assistants, who in vain attempted to prevent its extension.

In the next experiment, the left phrenic nerve was exposed at the outer edge of the sterno-thyroideus muscle. As this nerve is distributed to the diaphragm, and communicates with the heart through the pneumogastric nerves, it was expected that, by transmitting the galvanic fluid along it, the respiratory process might be renewed. Accordingly, a small incision having been made under the cartilage of the seventh rib, the point of one rod was brought into contact with the great head of the diaphragm, whilst that of the other was applied to the phrenic nerve in the neck. The diaphragm, which is a main agent in respiration, was instantly contracted, but with less force than was expected. "Satisfied," says Dr. Ure, "from ample experience on the living body, that more powerful effects can be produced in galvanic excitation by leaving the extreme communicating rods in close contact with the parts to be operated on, while the electric chain or circuit is completed by running the end of the wires along the top of the plates in the last trough of either pole, the other wire being steadily immersed in the last cell of the opposite pole, I had immediate recourse to this method. The success of it was truly wonderful. Full, nay laborious breathing instantly commenced. The chest heaved and fell; the belly was protruded and again collapsed, with the relaxing and retiring diaphragm. This process was continued, without interruption, as long as I continued the electric discharges. In the judgment of many scientific gentlemen who witnessed the scene, this respiratory experiment was perhaps the most striking ever made with a philosophical apparatus. Let it also be remembered, that for full half an hour before this period, the body had been well-nigh drained of its blood, and the spinal marrow severely lacerated. No pulsation could be perceived, meanwhile, at the heart or wrist; but it may be supposed, that but for the evacuation of the blood,—the essential stimulus of that organ,—this phenomenon might also have occurred."

In a third experiment, the supra-orbital nerve was laid bare in the forehead. The one conducting rod being applied to it, and the other to the heel, most extraordinary grimaces were exhibited. Every muscle in the face was simultaneously thrown into fearful action. "Rage, horror, despair, anguish, and ghastly smiles, united their hideous expression in the murderer's face, surpassing far the wildest representa-

a nerve towards its centre. See Bell's Select Medical Library, for Oct., 1839; Amer. Journ. of Med. Sciences, May, 1840, p. 13; and Medical Examiner, Jan. 23d and 30th, 1841.

tion of a Fuseli or of a Kean." At this period, several of the spectators were forced to leave the room from terror or sickness; and one gentleman fainted.

The last experiment consisted in transmitting the electric power from the spinal marrow to the ulnar nerve as it passes by the internal condyle at the elbow; when the fingers moved nimbly, like those of a violin performer; and an assistant who tried to close the fist, found the hand open forcibly in spite of every effort to prevent it. When one rod was applied to a slight incision in the tip of the forefinger, the fist being previously clenched, the finger was instantly extended; and from the convulsive agitation of the arm, he seemed to point to the different spectators, some of whom thought he had come to life.

The experiments of Dr. Ure have been several times repeated in this country on the bodies of criminals, and with analogous results.[1]

What important reflections are suggested by the perusal of such cases! The great resemblance between the galvanic and the nervous fluids, and the absorbing idea, to the philanthropist, that galvanism might be found successful in resuscitating the apparently dead, in cases where other means may have failed! Unfortunately, it can rarely happen, that the means will be at hand, so as to be available; and, moreover, when the heart has ceased to beat for a few minutes, it is generally impracticable to cause it to resume its functions.

An experiment, described by Dr. George Fordyce,[2] exhibits the power of contractility resident in the tissue. He slightly scratched, with a needle, the inside of a heart removed from the body, when it contracted so strongly as to force the point of the needle deep into its substance. This experiment has been often cited for the purpose of showing, that the mechanical effect, in such cases, is infinitely greater than the mechanical cause producing it; and hence, as we have endeavoured already to show, that all mechanical explanations must be insufficient to account for the phenomena of muscular contraction: we are compelled, indeed, to infer, that a new force must always be generated.

In the year 1806, a cause was tried before the Court of Exchequer in England, in which a better knowledge of the properties of muscle might have led to a different result.[3] According to the English law, where a man marries a woman seised of an estate of inheritance, and has, by her, issue born alive, which was capable of inheriting her estate,—in such case he shall, on the death of his wife, hold the lands for his life as *tenant by the courtesy* of England. It has, consequently, been a point of moment for the husband to show, that the child was born *alive;* and the law authorities have, with singular infelicity, attempted to define what shall be regarded evidences of this condition. According to Blackstone,[4] "it must be born alive. Some have had a notion that it must be heard to cry, but that is a mistake. Crying,

[1] Dunbar, in Baltimore Med. and Surg. Journal, i. 245, Balt., 1833, and the Journals referred to in the preceding pages.
[2] Philos. Transact. for 1788, p. 25.
[3] Taylor, Medical Jurisprudence, Amer. edit., by R. E. Griffith, p. 480, Philad., 1845.
[4] Commentaries, B. ii. 127.

indeed, is the strongest evidence of its being born alive, but it is not the *only* evidence." According to Coke,[1] "if it be born alive it is sufficient, though it be not heard to cry, for peradventure it may be born dumb.[2] It must be proved that the issue was alive; for *mortuus exitus non est exitus;* so that the crying is but a proof that the child was born alive; and so is motion, stirring, and the like." This latitudinarian definition has given occasion to erroneous decisions, as in the trial alluded to, in which the jury agreed that the child was born alive; because, although, when immersed in a warm bath immediately after birth, it did not "cry, or move, or show any symptoms of life;" yet, according to the testimony of two females,—the nurse and the cook,—there twice appeared a twitching and tremulous motion of the lips; and this was sufficient to make it fall under Lord Coke's definition. It is manifest, that, granting such motion to have actually occurred, it was of itself totally insufficient to establish the existence of somatic life. We have seen, that on the application of stimuli, the muscles of a body may be thrown into contraction for *two hours* after the cessation of respiration and circulation or after somatic death. Instead, therefore, of referring the irritability to the existence, at the time, of somatic life, it must be regarded simply as an evidence of the persistence of molecular life in parts that had previously and recently formed part of a living whole.

The contraction of a muscle is followed by its *relaxation;*—the fibres returning to their former condition. This appears to be a passive state; and to result from the suppression of the nervous influx by the will;—in other words, from the simple cessation of contraction. Some have, however, regarded both states to be active, but without proof. Barthez[3] maintains, that the relaxation of a muscle is produced by a nervous action the reverse of that which occasions its contraction;—the will relaxing the muscles as well as contracting them. The muscle is the only part susceptible of contraction. The tendon conveys the force developed by it, passively to the lever, which has to be moved.

It has been ascertained by MM. Becquerel and Breschet,[4] that a muscle during contraction augments in temperature. This increase is usually more than one degree of Fahrenheit; but at times when the exertion has been continued for five minutes,—as in the case of the biceps of the arm, in sawing wood,—it has been double that amount.[5]

Lastly, a sensation instructs the mind that a muscle has contracted, and this has given rise to the notion of a *muscular sense*, and a *sensation of motion:*—Muskelsinn, Bewegungssinn or *muscular sense* of Gruithuisen, Lenhossek,[6] Brown,[7] Sir C. Bell,[8] and other

[1] Institutes, 30, a.

[2] It need scarcely be said that the deaf-dumb cry at the moment of birth the same as other children. The natural cry is effected by them as well as by the infant that possesses all its senses. It is the *acquired* voice, alone, which they are incapable of attaining.

[3] Nouveaux Elémens de la Science de l'Homme, Paris, 1806.

[4] Archiv. du Muséum, tom. i. p. 402, and Annales des Sciences Naturelles, nouv. série, iii. 272.

[5] See on this subject Helmholtz, in Müller's Archiv., H. ii. s. 144, Berlin, 1848.

[6] Rudolphi, Grundriss der Physiologie, 2te Band, 1ste Abtheil., s. 318, Berlin, 1823.

[7] Lectures on Moral Philosophy.

[8] The Hand, &c., Amer. edit., p. 145, Philad., 1833.

writers. It appears to be an internal sensation, produced by the muscle pressing on the sensible parts surrounding it, which convey the sensation to the brain. It is by this muscular sense that the brain learns to adapt the effort to the effect to be produced. Without it no precision could exist in the movements of the muscles, and every manual effort—whether of the artist or the mechanic—would be confused and disorderly. The step, too, would be unsteady and insecure. "In chewing our food," says Dr. A. Combe,[1] "in turning the eyes towards an object looked at, in raising the hand to the mouth, and, in fact, in every variety of muscular movement which we perform, we are guided by the muscular sense in proportioning the effect to the resistance to be overcome; and where this harmony is destroyed by disease, the extent of the service rendered us becomes more apparent. The shake of the arm and hand which we see in drunkards, and their consequent incapability of carrying the morsel directly to the mouth, are examples of what would be of daily occurrence, unless we were directed and assisted by a muscular sense." It enables us to form ideas of force and resistance, by conveying to our minds a distinct idea of the effort required.

The *force* or *intensity of muscular contraction* is dependent upon two causes,—the physical condition of the muscle, and the energy of the brain. A muscle, which is composed of large, firm fibres, will contract,—the energy of the brain being equal,—more forcibly than one with delicate, loose fibres. Volition generally determines the degree of power developed by the voluntary motions; and is accurately regulated so as to raise a weight of one pound or one hundred. We notice astonishing efforts of strength in those that are labouring, at the time, under strong cerebral excitement; mania, rage, delirium, &c. In such cases, the delicate muscles of the female are capable of contracting with a force far transcending that of the healthy male. The power of muscular contraction is, therefore, in a compound ratio with the strength of the organization of the muscle, and the degree of excitation of the brain. When both are considerable, the feats of strength surpass belief; and where both are small, the results are insignificant. The extensors of the knee and foot occasionally contract with so much violence as to fracture the patella and tendo Achillis, respectively. The force, developed in the calf of the leg, must be great, when a person stands on tiptoe with a burden on his head or shoulders; or when he projects his body from the soil, as in leaping. Rudolphi[2] asserts, that he has seen a horse, which fractured its under-jaw by biting a piece of iron.

It has been a question, whether the power of a muscle is greater or less at different degrees of contraction, the same stimulus being applied. To determine this, Schwann[3] invented an apparatus, which should accurately measure the length of the muscle, and the weight it would balance by its contraction; and, from his experiments it appeared, that a uniform

[1] Principles of Physiology, 5th edit., p. 131, Edinb., 1836.
[2] Op. cit., p. 303.
[3] J. Müller, Physiology, p. 903.

increase of force is attended with a nearly uniform increase in the length of the muscle. The explanation of this by Dr. Carpenter[1] is probably correct;—that, as the observations of Mr. Bowman have clearly shown, there must be a considerable displacement of the constituents of every fibre during contraction, it is easy to understand, that the greater the contraction the more difficult must any farther contraction become. "If, between a magnet and a piece of iron attracted by it, there were interposed a spongy elastic tissue, the iron would cease to approach the magnet at a point, at which the attraction of the magnet would be balanced by the force needed to compress still farther the intermediate substance."

We have a number of feats of surprising strength on record, several of which have been collected by Sir David Brewster.[2] Of these, the cases of John Charles Van Eckeberg, who travelled through Europe under the appellation of Samson, and of Thomas Topham, are the most authentic and extraordinary. Dr. Desaguliers saw Topham, by the strength of his fingers, roll up a very strong and large pewter dish. He broke seven or eight short and strong pieces of tobacco-pipe with the force of his middle finger, having laid them on his first and third fingers. Having thrust under his garter the bowl of a strong tobacco-pipe, his leg being bent, he broke it to pieces by the tendons of his hams without altering the flexure of his knee. He broke another such bowl between his first and second fingers, by pressing his fingers together sideways. He lifted a table six feet long—which had half a hundred weight hanging at the end of it—with his teeth, and held it in a horizontal position for a considerable time, the feet of the table resting against his knees. He took an iron kitchen poker, about a yard long, and three inches in circumference, and, holding it in his right hand, he struck upon his bare left arm, between the elbow and wrist, till he bent the poker nearly to a right angle. He took such another poker, and holding the ends of it in his hands, and the middle against the back of his neck, he brought both ends of it together before him; and afterwards pulled it nearly straight again. He broke a rope about two inches in circumference, which was in part wound about a cylinder of four inches in diameter, having fastened the other end of it to straps that went over his shoulders. Lastly, he lifted a rolling-stone, eight hundred pounds in weight, with his hands only, standing in a frame above it, and taking hold of a chain that was fastened to it.

An equally remarkable example is given by a recent well-known traveller[3] as having been witnessed by him in Paris. In the Place du Carrousel, a large coarse French woman made the following exhibition in the presence of a great crowd of spectators. A rough block of stone, weighing more than three hundred pounds, and which two men could barely lift from the ground, was fastened round with several turns of rope. The long black hair of the woman, which was divided into seven traces, tightly platted and fastened at the end, was then brought

1 Human Physiology, § 394, Lond., 1842.
2 Letters on Natural Magic, Amer. edit., p. 222, New York, 1832.
3 J. S. Buckingham, Travels in France, Piedmont, &c., ii. 63, Lond., 1849

down, and attached to these ropes, whilst the woman herself bent her head back towards the stone for the purpose of admitting of the traces being fastened. When this was done, she slowly rose to her erect position, lifting the stone entirely from the ground, its weight being borne by the seven traces of her hair, and the pressure resting wholly on her scalp. She then began to turn herself slowly round, swinging the stone just fastened to her hair, until, by the progressively increasing motion, she twirled round as rapidly as the spinning dervishes, or an opera dancer in a pirouette, but for a longer period,—the stone all this while going out farther and farther from her person till it swung round almost horizontally, and with a velocity that made it fearful to look upon, relaxing gradually from the highest point of motion till it rested at her feet. It was then loosened from the hair and the cords; and her next feat was to place two rush-bottomed chairs at a distance of about four feet and a half from each other, when she placed her head on one, and her heels on the other, thus lying horizontally between the two, without any support for her back or loins in the centre, and neither her head nor her heels being more than six inches from the outer edge of the chairs. Whilst in this condition, two men were invited to come from the crowd and lift up the stone, so as to place it on her stomach. Two persons came from amongst the bystanders, and one of them not being a strong man, they were unable to lift it, when a third came to their assistance; but not till after at least twenty persons had tried to lift the stone a little from the ground, to be assured it was not hollow, and that there was no deception, and each had failed to lift it half an inch from where it stood. The three men, however, raised it up, and placed it on the woman's stomach, as she lay in this horizontal position; when another person, at her request, placed a smaller stone on the large one, and with a heavy iron sledge-hammer broke it into twenty pieces. All this occupied about a quarter of an hour, during the whole of which time the woman evinced no appearance of shrinking; and in conversing with her after she rose there was not the slightest evidence of any inconvenience being felt by her from the exertion.

That much depends upon physical organisation, as regards the force of muscular contraction, is evinced by the fact of the great difference in the various races of mankind. On our own continent, numerous opportunities have occurred for witnessing the inferiority, in strength, of the aborigines to the white settlers. Péron[1] took with him, in his voyage round the world, one of Regnier's dynamometers, which indicate the relative force of men and animals. He directed his attention to the strength of the arms and loins, making trial on several individuals of different nations; twelve natives of Van Diemen's Land; seventeen of New Holland; fifty-six of the island of Timor; seventeen Frenchmen belonging to the expedition, and fourteen Englishmen in the colony of New South Wales. The following was the mean result:—

[1] Voyage, &c., tom. i. chap. xx. p. 446; and t. ii. p. 461; and Lawrence's Lectures on Physiology, &c., p. 404, Lond., 1819.

	STRENGTH	
	Of the Arms. *Kilogrammes.*[1]	Of the Loins. *Myriagrammes.*
1. Van Diemen's Land,	50·6	
2. New Holland,	50·8	10·2
3. Timor,	58·7	11·6
4. French,	69·2	15·2
5. English,	71·4	16·3

The highest numbers, in the first and second divisions, were respectively 60 and 62; the lowest in the fifth, 63; in the highest 83, for the strength of the arms. In the power of the loins, the highest amongst the New Hollanders was 13; the lowest of the English, 12·7.[2]

The force of muscular contraction is also largely increased by the proper exercise of the muscles. Hence the utility of the ancient gymnasia. In early times, muscular energy commanded respect and admiration. It was the safeguard of individuals and families, and the protection of nations; and it was esteemed a matter of national policy to encourage its acquisition. In modern times, the invention of gunpowder having altered the system of warfare, and given to skill the superiority which strength communicated in personal combats, institutions for the developement of the muscular system have been abandoned, until of comparatively late years. They afford us striking examples of the value of muscular exertion, not only in giving energy and pliancy to the frame, but as a means of preserving health.

The mean effect of the labour of an active man, working to the greatest possible advantage, and without impediment, is usually estimated to be sufficient to raise ten pounds, ten feet in a second for ten hours in a day; or to raise one hundred pounds, which is the weight of twelve wine gallons of water, one foot in a second, or thirty-six thousand feet in a day; or three millions, six hundred thousand pounds, or four hundred and thirty-two thousand gallons, one foot in a day. Dr. Desaguliers affirms, that the weakest men who are in health, and not too fat, lift about one hundred and twenty-five pounds; and the strongest of ordinary men four hundred pounds. Topham lifted eight hundred. The daily work of a horse is estimated to be equal to that of five or six men.

In insects, the force of muscular contraction appears to be greater in proportion to their size than in any other animals. The *Lucanus cervus* or *Stag Beetle* has been known to gnaw a hole of an inch diameter in the side of an iron canister in which it had been confined, and many striking examples of a similar kind are given hereafter under the head of FLYING.

In the *duration* of muscular contraction we notice considerable difference between the voluntary and involuntary muscles; the latter being much more rapid and alternating. The same remark applies to the

[1] The approximate value of a *kilogramme* is about two pounds avoirdupois:—of a *myriagramme* about twenty.

[2] See Quetelet, Sur l'Homme, &c., Paris, 1835, or English edit., by Dr. R. Knox, p. 67, Edinburgh, 1842. Prof. Forbes, of Edinburgh, in London and Edinburgh Phil. Magazine, for March, 1837, p. 197; and in Dunglison's American Med. Intelligencer, for May 15, 1837, p. 74; in which are detailed experiments on the weight, height, and strength of above eight hundred individuals, natives of England, Scotland, Ireland, and Belgium.

voluntary muscles, when excited by another stimulus than that of the will. Contraction, excited by volition, can be maintained for a considerable time: of this we have examples in bearing a burden; the act of standing; holding the arm extended from the body, &c. In all these cases, the contractility of the muscles is sooner or later exhausted; fatigue is experienced; and it becomes necessary to give them rest; the power of contractility, however, is soon resumed, and they can be again put in action. This law of intermission in muscular action appears absolute;—relaxation being followed by contraction, in every organ, from the commencement of life until its final cessation. The intermission, has, indeed, by many physiologists, been held to prevail—to a slight extent only, it is true—during what we are in the habit of considering continuous, muscular contraction. In proof of this, they cite the fact, that when we put the tip of the finger into the meatus auditorius externus, we hear a kind of buzzing or humming, which does not occur when an inert body is introduced.[1] There are, however, other actions going on in the finger besides muscular contraction; and the buzzing might, with as much propriety, be referred to the noise made by the progression of fluids in the vessels, as to the oscillations of muscular contraction and relaxation. We know not, in truth, whence the sound immediately proceeds.

In the *velocity* of muscular contraction, much difference exists, according to the stimulus which sets it in action. If we apply galvanism to a muscle, we find the contractions at first exceedingly rapid; but they become progressively feebler, and require a stronger stimulus, until their irritability appears to be exhausted. Irritating the nerve in these cases is found to produce a greater effect, than when the stimulus is applied directly to the muscle. The velocity of voluntary contraction is, of course, variable, being regulated entirely by the will. We have, in various classes of the animal kingdom, remarkable instances of this velocity. The motions of the racer, greyhound, practised runner, the fingers in playing on musical instruments—as the violin, flute, pianoforte,—and in writing; of the voice in enunciation, and of the upper and lower limbs in striking, leaping, and kicking, convey a general notion of this rapidity of contraction; and how nicely, in many cases, it must be regulated by volition. The fleetest race-horse on record was capable of going, for a short distance, at the rate of a mile per minute; yet this is trifling, when compared with the velocity of certain birds, which can, with facility, wheel round and round the most rapid racer in circles of immense diameters,—and with that of numerous small insects, which accompany us, with apparent facility, when we travel with great rapidity, even against the wind.

It has frequently excited surprise, how the migratory birds can support themselves so long upon the wing as to reach the country of their migration; and, at the same time, live without food during their aerial voyage. The difficulties of the subject have impelled many to deny the fact of their migration, and excited others to form extravagant theories to account for the preservation of the birds during the winter

[1] Wollaston, in Philosoph. Transact. for 1810, p. 2.

months; but if we attend to their excessive velocity, the difficulties, in a great measure, vanish. "Nothing," says Wilson,[1] "is more common in Pennsylvania than to see large flocks of the bluebirds, in spring and fall, passing at considerable heights in the air,—from the south in the former, from the north in the latter season. The Bermudas are said to be six hundred miles from the nearest part of the continent. This may seem an extraordinary flight for so small a bird; but it is a fact that it is performed. If we suppose the bluebird to fly only at the rate of a mile a minute, which is less than I have actually ascertained them to do over land, ten or twelve hours would be sufficient to accomplish the journey." Montagu, a celebrated ornithologist, estimates the rapidity with which hawks and many other birds occasionally fly to be not less than one hundred and fifty miles an hour; and that one hundred miles per hour is certainly not beyond a fair computation for the continuance of their migration. Major Cartwright, on the coast of Labrador, found by repeated observations, that the flight of the eider duck is at the rate of ninety miles an hour; yet it has not been esteemed very remarkable for its swiftness. Sir George Cayley computes the rate of flight of the common crow at nearly twenty-five miles an hour. Spallanzani found that of the swallow about ninety-two miles an hour; and he conjectures, that the velocity of the swift is nearly three times greater. A falcon belonging to Henry IV. of France escaped from Fontainbleau, and was in twenty-four hours afterwards at Malta,—a distance computed to be not less than one thousand three hundred and fifty miles, making a velocity of nearly fifty-seven miles an hour, supposing the falcon to have been on the wing the whole time; but, as such birds never fly by night, if we allow the day to have been at the longest, his flight was perhaps at the rate of seventy-five miles per hour. It is not probable, however, as Montagu observes, that it had either so many hours of light in the twenty-four to perform its journey, or that it was retaken at the moment of its arrival.[2] A society of pigeon-fanciers from Antwerp despatched ninety pigeons from Paris, the first of which returned in four hours and a half, at a rate of nearly fifty miles an hour. Out of one hundred and ten pigeons, carried from Brussels to London in the summer of 1830, and let fly from London on July 19th, at a quarter before nine A.M., one reached Antwerp, one hundred and eighty-six miles distant, at eighteen minutes past two, or in five and a half hours,—being at the rate of nearly thirty-four miles an hour. In another case, one went from London to Maestricht, two hundred and sixty miles, in six and a quarter hours. In January, 1831, two pigeons, carried from Liskeard to London, were let loose in London. One reached Liskeard, two hundred and twenty miles distant, in six hours; the other in a quarter of an hour more.[3] There is an instance of the migratory or passenger pigeon—*Columba migratoria* of Wilson—having been shot in Fifeshire, in Scotland. It was the first ever seen in Great Britain, and had been forced over, it was imagined, by unusually strong westerly gales.[4]

[1] American Ornithology, ii. 178.
[2] Fleming's Philosophy of Zoology, ii. 42, Edinb., 1822.
[3] Turner's History of the World, Amer. edit., i. 259, New York, 1832.
[4] New Monthly Magazine for 1826.

The velocity of the contraction of the muscles of the wings, in these rapid flights, is incalculable. The possible velocity, in any case, must be greatly dependent upon habit. Nothing can be more awkward than the first attempts at writing, drawing, playing on musical instruments, or performing any mechanical process in the arts; and what a contrast is afforded by the astonishing celerity, which practice never fails to confer, in any one of those varieties of muscular contraction! In running, leaping, wrestling, dancing, or any other motion of the body, one person can execute with facility what another, with equally favourable original powers, cannot effect, because he has not previously and frequently made the attempt. Prize-fighting affords an instance of this kind of muscular velocity and precision acquired by habit,—the practised boxer being able to inflict his blow and return his arm to the guard so quickly as almost to elude the sight. By considering the muscular motions, employed in transporting the body of the fleetest horse, Haller concluded, that the elevation of the leg must have been performed in $\frac{1}{70}$th of a second. He calculates, that the *rectus femoris*,—the large muscle which is attached to the knee-pan and extends the leg,—is shortened three inches in the $\frac{1}{28}$th of a second in the most rapid movements of man. But, he adds, the quickest motions are executed by the muscles concerned in the articulation of the voice. He himself, in one experiment, pronounced fifteen hundred letters in a minute; and as the relaxation of a muscle occupies as much time as its contraction, the contraction of a muscle, in pronouncing one of these letters, must have been executed in $\frac{1}{3000}$th part of a minute; and in much less time in some letters, which require repeated contractions of the same muscle or muscles as *r*. If the tremors, that occur in the pronunciation of this letter, be estimated at ten, the muscles concerned in it must have contracted in Haller's experiment, in $\frac{1}{30000}$th part of a minute.[1] It has been calculated, that all the tones of which the human voice is capable are produced by a variation of not more than one-fifth of an inch in the length of the vocal cords; and that in man the variation required to pass from one interval to another will not be more than $\frac{1}{1200}$th of an inch. These cases are, however, far exceeded by the rapidity of the vibrations of the wings of insects, which can be estimated from the musical tone they induce, experiment having shown the number of vibrations required to produce any given note. The vibrations of their wings have thus been found to amount to several thousands per second.

It has been the opinion of many physiologists and metaphysicians, that muscular contraction is only directed by volition within certain limits of velocity; and that when it exceeds a certain velocity it depends upon habit. The effects of volition have, in this respect, been divided into the *immediate* and *remote*. Of the first we have examples in the formation of certain vocal and articulate sounds; and in certain motions of the joints, as in the production of voice, speech, and locomotion. In the second, those actions are included which we conceive to be within our power, but in which we think of the end to be obtained, without attending to the mechanical means. "In learning a language,

[1] Elementa Physiologiæ, &c., lib. xi. 2, Lausan., 1757–1766.

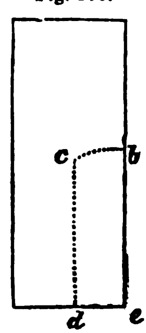
for example," says Dr. Bostock,[1] "we begin by imitating the pronunciation of the words, and use a direct effort to put the organs of speech in the proper form. By degrees, however, we become familiar with this part of the operation, and think only of the words that are to be employed, or even the meaning that is to be conveyed by them. In learning music, we begin by imitating particular motions of the fingers, but at length the fingers are disregarded, and we only consider what sounds will follow from certain notes, without thinking of the mechanical way in which the notes are produced." In these, however, and in all other cases that can be brought forward, it is difficult to conceive how the effect can be produced without the agency of volition,—obscure it is true, but still in action. The case of reading is often assumed, as confirming the view that invokes habit; yet, if a letter be inverted, we immediately detect it; and although, by habit, we may have acquired extreme facility in playing the notes of a rapid musical movement, no doubt, we think, ought to exist, that an effort of volition is exerted on each note composing it,—inasmuch as there is no natural sequence of sounds; and hence there appears no cogent reason, why one should follow rather than another, unless a controlling effort of the will were exerted.

With regard to the *extent* of muscular contraction, this must of course be partly regulated by volition; but it is also greatly owing to the length of the muscular fibres. The greater the length, of course the greater the decurtation during contraction. We shall see, likewise, that this depends upon the kind of lever, which the bone forms, and the distance at which the muscle is inserted from the joint or fulcrum.

Before passing to the examination of special movements, it will be necessary to consider briefly certain elementary principles of mechanics, most of which are materially concerned in every explanation, and without some knowledge of which such explanation would, of course, be obscure or unintelligible. Were we, as M. Magendie[2] has remarked, to investigate narrowly every motion of the body, we should find the applicability of almost all the laws of mechanics to them.

If we take a rod of wood or metal, of uniform matter throughout, and support it at the middle, either like the beam of a balance, or on a pointed body, we find, that the two ends accurately balance each other; and if we add weights at corresponding parts of each arm of the beam, that is, at parts equidistant from the point of suspension, the balance will still be maintained. The point by which the beam is suspended, or at which it is equilibrious, is called its *centre of gravity;* and, in every mass of matter, there is a point of this kind, about which all the parts balance or are equilibrious; or, in other words, they have all a centre of gravity or inertia. The centre of gravity, in a mass of regular form and uniform substance, as in the parallelograms, Figs. 168 and 169, is easily determined, inasmuch as it must necessarily occupy the centre *c;* but in bodies that are irregular, either as regards density or

Fig. 168.



Centre of Gravity.

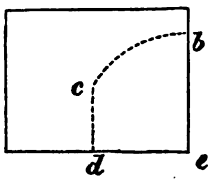
[1] Physiology, edit. cit., p. 774, Lond., 1836.

[2] Précis, &c., edit. cit., i. 276.

form, it has to be determined by rules of calculation, to be found in all works on physics; but which it is unnecessary to adduce here.

The nearer the centre of gravity is to the soil on which the body rests, the more stable is the equilibrium. In order that the Figures 168 and 169 shall be overturned from left to right, the whole mass must turn upon *e* as upon a pivot; the centre of gravity describing the curve *c b*, and the whole mass being lifted in the same degree. In Fig. 168, the curve is nearly horizontal, owing to the narrowness of the base and the height of the centre of gravity. In Fig. 169, on the other hand, whose base is broad and the centre of gravity low, the curve rises considerably; the resistance to overturning is consequently nearly equal to the whole weight of the body, and the equilibrium necessarily firm.

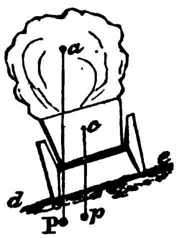
Fig. 169.



Centre of Gravity.

The *condition of equilibrium* of a body resting upon a plane is such, that a perpendicular, let fall from the centre of gravity, shall fall within the points by which it touches the plane. This perpendicular is called *vertical line* or *line of direction*, being that in which it tends naturally to descend to the earth; and the space comprised between the points by which the body touches the soil is called *base of sustentation*. We can now understand, why a wagon, loaded with heavy goods, may pass with safety along a sloping road; whilst, if it be loaded to a greater height with a lighter substance, it may be readily overturned. When the wagon is loaded with metal, the centre of gravity is low, as at *c*, Fig. 170; the vertical line *c p* falls considerably within the base of sustentation; and the centre describes a rising path; but in the other case the centre is thrown higher, to *a;* and the vertical line falls very near the wheel, or on the outside of it, and consequently of the base, whilst the centre describes a falling path.

Fig. 170.



Condition of Equilibrium.

Of two hollow columns, formed of an equal quantity of the same matter, and of the same height, that which has the largest cavity will be the stronger; and of two columns of the same diameter, but of different heights, the higher will be the weaker.

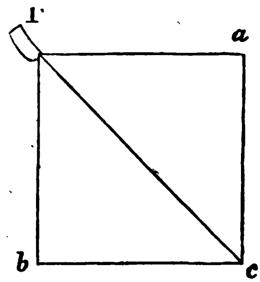
All bodies tend to continue in the state of motion or of rest, so as to render force necessary to change their state. This property is called the *inertia of motion*, or of *rest*, as the case may be. When a carriage is about to be moved by horses, considerable effort is necessary to overcome the *inertia of rest;* but if it moves with velocity, effort is required to arrest it, or to overcome the *inertia of motion*. We can thus understand why, if a horse start unexpectedly, it is apt to get rid of its burden; and why an unpractised rider is projected over his horse's head if it stops suddenly. In the former case, the inertia of rest is the cause of his being thrown; in the latter, the inertia of motion. The danger of attempting to leap from a carriage, when the horses have taken fright, is thus rendered apparent. The traveller has acquired the same velocity as the vehicle; and if he leaps from it, he is thrown

to the ground with that velocity; thus incurring an almost certain injury to avoid one remotely contingent.

The *force*, *momentum*, or *quantity of motion* in a body is measured by the velocity, multiplied into the quantity of matter. A cannon-ball, for example, may be rolled so gently against a man's leg, as not even to bruise it; but if it be projected by means of gunpowder, it may mow down a dense column of men, or penetrate the most solid substance. If a man be running, and strike against another who is standing, a certain shock is received by both; but if both be running in opposite directions with the same velocity, the shock will be doubled.

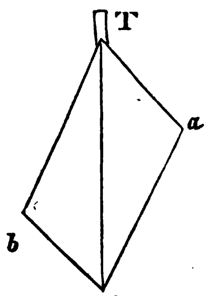
The subject of the direction of forces applies to most cases of muscular movement. Where only one force acts upon a body, the body proceeds in the direction in which the force is exerted, as in the case of a bullet fired from a gun; but if two or more forces act upon it at the same time, the direction of its motion will be a middle course between the direction of the separate forces. This course is called the *resulting direction*, that is, *resulting* from the *composition of the forces*. Let us suppose two forces *a* T and *b* T in Fig. 171, acting upon the body T, which may be regarded as the tendon of a muscle, and the two forces as the power developed by muscular fibres holding the same situation; the result will be the same, whether they act together or in succession. For example, if the force *a* T is sufficient to draw T to *a*, and immediately afterwards the force *b* T be exerted upon it, the tendon will be at *c*, the place towards which it would be drawn by the simultaneous action of the two forces or fibres. If, therefore, we complete the figure, by drawing *a c* equal and parallel to T *b*, and *c b* equal and parallel to *a* T, we have the *parallelogram of forces*, as it is called, of which the diagonal shows the *resultant* of the forces, and the course of the body on which they act. In the case, assumed in Fig. 171, the forces are equal. If not, the parallelogram may result as in Fig. 173; in which T *c* will, again, be the resultant of the forces *a* T and T *b*, or we may have the arrangement in Fig. 172.

Fig. 171.



Composition of Forces.

Fig. 172.



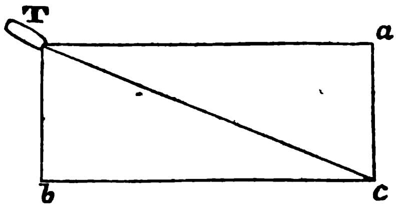
Composition of Forces.

By these parallelograms, we are enabled, also, to resolve the resultant into its component forces. Suppose, for example, we desire to know the quantity of force in the resultant, T *c*, Fig. 171, which is capable of acting in the directions T *a* and T *b*; it is only necessary to draw, from the point *c*, *c a* parallel to T *b*, and *c b* parallel to T *a*; and the lines T *a* and T *b*, cut off by these, will be the forces into which it may be resolved. The same applies to Figs. 172 and 173, and to every other of the kind.

Friction is the resistance necessary to be overcome in making one

body slide over another; and *adhesion* the force, which unites two polished bodies when applied to each other, — a force, which is measured by the perpendicular effort necessary for separating the two bodies. The more polished the surfaces in contact, the greater is the adhesion, and the less the friction; so that where the object is merely to facilitate the sliding of one surface over another, it will be always advantageous to make the surfaces polished, or to put a liquid between them.

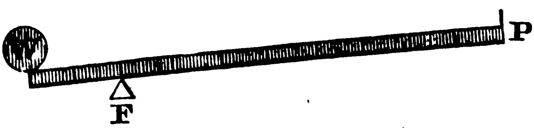
Fig. 173.



Composition of Forces.

A beam or rod of any kind, resting at one part on a prop or support, which thus becomes its centre of motion, is a *lever*. The ten inch beam, P W, Fig. 174, is a lever, of which F may be considered the *prop* or *fulcrum;* P, the part at which the *power* is applied, and W, the point of application of the *weight* or *resistance*.

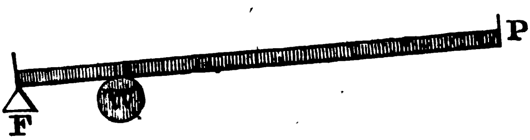
Fig. 174.



Lever of the first kind.

In every lever we distinguish three points;—the *fulcrum*, *power*, and *resistance;* and, according to the relative position of these points, the lever is said to be of the *first*, *second*, or *third kind*. In a lever of the first kind, the fulcrum is between the resistance and power, as in Fig. 174; F being the fulcrum on which the beam rests and turns; P, the power; and W, the weight or resistance. We have numerous familiar examples of this lever;—the crowbar in elevating a weight; the handle of a pump; a pair of scales; a steelyard, &c. A *lever of the second kind* has the resistance W, Fig. 175, between the power P and the fulcrum F; the fulcrum and power occupying each one extremity. The rudder of a ship, a wheelbarrow, and nut-crackers, are varieties of this kind of lever. In a *lever of the third kind*, the power P is between the resistance W, and the fulcrum F, Fig. 176; the resistance and the fulcrum occupying each one extremity of the lever. In the last two levers, the weight and the power change places. Tongs and shears are levers of this kind; also, a long ladder raised against a wall by the efforts of a man: here the fulcrum is at the part of the ladder which rests on the ground; the power is exerted by the man; and the resistance is the ladder above him.

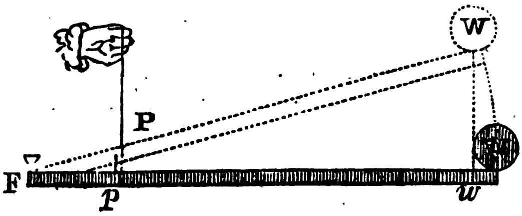
Fig. 175.



Lever of the second kind.

In all levers are distinguished,—the *arm of the power* and the *arm of the resistance*. The former is the distance comprised between the power and the fulcrum, P F, Figs. 174, 175, and 176; and the latter is the distance W F, or that between the weight and the fulcrum. When, in the lever of the first kind, the fulcrum occupies the middle, the lever is said to have equal arms; but if it be nearer the power or the resistance, it is said to be a lever with unequal arms.

Fig. 176



Lever of the third kind.

The length of the arm of the lever gives more or less advantage to the power, or the resistance, as the case may be. In a lever of the first kind, with equal arms, complete equilibrium would exist, provided the beam were alike in every other respect. But if the arm of the power be longer than that of the resistance, the resistance is to the power as the length of the arm of the power is to that of the arm of the resistance; so that if the former be double or triple the latter, the power need only be one-half or one-third of the resistance, in order that the two forces may be in equilibrium. A reference to the figures will exhibit this in a clear light. The three levers are all presumed to be of equal substance throughout, and to be ten inches, or ten feet, in length. The arm of the power, in Fig. 174, is the distance P F, equal to eight of those divisions; whilst that of the resistance is W F, equal to two of them. The advantage of the former over the latter is, consequently, in the proportion of eight to two, or as four to one; in other words, the power need only be one-fourth of the resistance, in order that the two forces may be equilibrious. In the lever of the second kind, the proportion of the arm P F of the power is to that of the resistance, W F, as ten—the whole length of the lever—to two; or five to one; whilst, in the lever of the third kind, it is as two to ten, or as one to five; in other words, to be equilibrious, the power must be five times greater than the resistance. We see, therefore, that in the lever of the second kind, the arm of the power must necessarily be longer than that of the resistance, since the power and the fulcrum are separated from each other by the whole length of the lever; hence this kind of lever must always be advantageous to the power; whilst the lever of the third kind, for like reasons, must always be unfavourable to it, seeing that the arm of the resistance is the whole length of the lever, and, therefore, necessarily greater than that of the power.

It can now be understood why a lever of the first kind should be most favourable for equilibrium; one of the second for overcoming resistance; and one of the third for rapidity and extent of motion: for whilst, in Fig. 176, the power is moving through the minute arc at P,

in order that the lever may assume the position indicated by the dotted lines F w, the weight or resistance is moving through the much more considerable space W *w*.

The direction in which the power is inserted into the lever likewise demands notice. When perpendicular to the lever, it acts with the greatest advantage,—the whole of the force developed being employed in surmounting the resistance; whilst if inserted obliquely a part of the force is employed in tending to move the lever in its own direction; and this part is destroyed by the resistance of the fulcrum.

Lastly: the general principles of equilibrium in levers consist in this;—that whatever may be the direction in which the power and resistance are acting, they must always be to one another inversely as the perpendiculars drawn from the fulcrum to their lines of direction. In Fig. 176, for example, the line of direction of the upper weight is W *w*; that of the power P *p*; and, to keep the lever in equilibrium in this position, the forces must be to one another inversely as F *w* to F *p*.

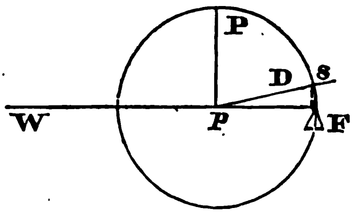
In applying these mechanical principles to the illustration of muscular motion, we must, in the first place, regard each movable bone as a lever, whose fulcrum or centre of motion is in its joint; the power at the insertion of the muscle; and the resistance in its own weight and that of the parts which it supports. In different parts of the skeleton we find the three kinds of levers. Each of the vertebræ of the back forms, with the one immediately beneath it, a lever of the first kind,—the fulcrum being seated in the middle of the under surface of the body of the vertebra. The foot, when we stand upon the toe, is a lever of the second kind,—the fulcrum being in the part of the toes resting upon the soil; the power in the muscles inserted into the heel, and the resistance in the ankle-joint, on which the whole weight of the body rests. Of levers of the third kind we have numerous instances; of which the deltoid, to be described presently, is one. In this, as in other cases, the applicability of the principle, laid down regarding the arms of the lever, &c., is seen, and we find, that, in the generality of cases, the power is inserted into the lever so near to the fulcrum, that considerable force must be exerted to raise an inconsiderable weight;—that so far, consequently, mechanical disadvantage results; but such disadvantage enters into the economy of nature, and is attended with so many valuable concomitants as to compensate richly for the expense of power. Some of these causes, that tend to diminish the effect of the forces, we shall first consider, and afterwards attempt to show the advantages resulting from these and similar arrangements in effecting the wonderful, complicate operations of the muscular system.

In elucidation of this subject, we may take, with Haller,[1] the case of the deltoid—the large muscle, which constitutes the fleshy mass on the top of the arm, and whose office it is to raise the upper extremity. Let W F, Fig. 177, represent the os humeri, with a weight W at the elbow, to be raised by the deltoid D. The fulcrum F is necessarily, in this case, in the shoulder joint; and the muscle D is inserted much

[1] Elementa Physiologiæ, lib. xi. 2.

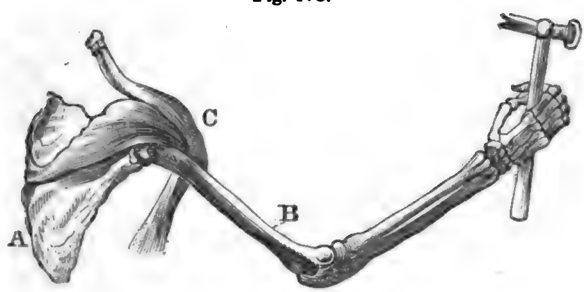
nearer to the fulcrum than to the end of the bone on which the weight rests; the arm of the power *P* F,—(supposing, for a moment, that it is acting at this part with every advantage, which we shall see presently it is not,)—is, consequently, much shorter than that of the resistance W F, which, as in all levers of the third kind, occupies the whole length of the lever. In estimating the effect from this cause alone upon the power to be exerted by the deltoid, we may suppose, that the arm of the power is to that of the resistance as 1 to 3;—the deltoid being inserted into the humerus about one-third down. Now, if we raise a weight of fifty-five pounds in this way, and add five pounds for the weight of the limb—(which may be conceived to act entirely at the end of the bone)—the power, which the deltoid must exert to produce the effect, is equal not to sixty pounds, but to three times sixty or one hundred and eighty pounds.

Fig. 177.



Action of the Deltoid.

Fig. 178.



Action of the Deltoid.

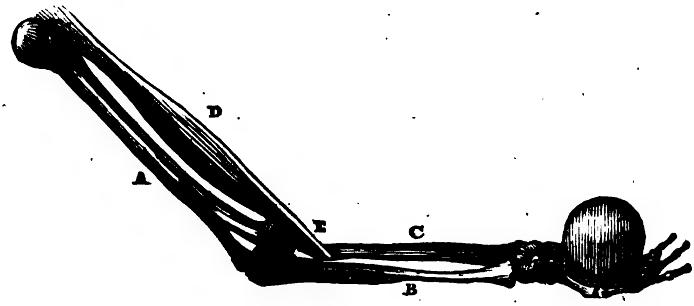
A. The scapula. B. The os humeri. C. The deltoid.

Figures 177 and 178 exhibit the disadvantages of the deltoid, so far as regards the place of its insertion into the lever; but many muscles have insertions much less favourable than it. The biceps, D, for example, in Fig. 179,—the muscle which bends the forearm on the arm,—is attached to the forearm ten times nearer the elbow-joint or fulcrum than to the extremity of the lever; and if we apply the argument to it,—supposing the weight of the globe, in the palm of the hand, to be fifty-five pounds and the weight of the limb five pounds,—it would have to act with a force equal to sixty times ten, or six hundred pounds, to raise the weight.

Muscles, again, are attached to the bones at unfavourable angles. If they were inserted at right angles in the direction P *P*, Fig. 177, the whole power would be effectually applied in moving the limb. On the other hand, if the muscle were parallel to the bone, the resistance would be infinite, and no effect could result. In the animal it rarely

happens, that the muscle is inserted at the most favourable angle: it is generally much smaller than a right angle. Reverting to the deltoid, this muscle is inserted into the humerus at an angle of about ten de-

Fig. 179.



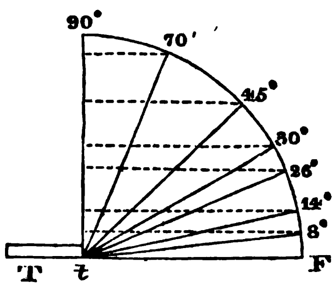
Action of the Biceps.

A. The os humeri. B. The ulna. C. The radius. D. The biceps. E. Insertion of the biceps into the radius.

grees. Now, a power acting obliquely upon a lever, is to one acting perpendicularly, as the sine of inclination, represented by the dotted line F s, Fig. 177, to the whole sine P *P*. In the case of the deltoid, the proportion is as 1,736,482 to 10,000,000. Wherefore, if the muscle had to contract with a force of one hundred and eighty pounds, owing to the disadvantage of its insertion near the fulcrum, it would have, from the two causes combined, to exert a force equal to 1,058 pounds.

Again, the direction in which the fibres are inserted into the tendon has great influence on the power developed by the muscle. There are few straight muscles, in which all the fibres have the same direction as the tendon. Fig. 180 will exhibit the loss of power, which the fibres must sustain in proportion to the angle of insertion. The fibre *t* F would, of course, exert its whole force upon the tendon, whilst the fibre *t* 90°, by its contraction, would merely displace the tendon. Now, the force exerted is, in such case, to the effective force,—that is, to that which acts in moving the limb,—as the whole sine *t* F is to the sines of the angles at which the fibres join the tendon represented by the dotted lines. Borelli and Sturm have calculated these proportions as follows:—At an angle of 30°, they are as 100 to 87; at 45° as 100 to 70; at 26° as 100 to 89; at 14° as 100 to 97; and at 8° as 100 to 99.

Fig. 180.



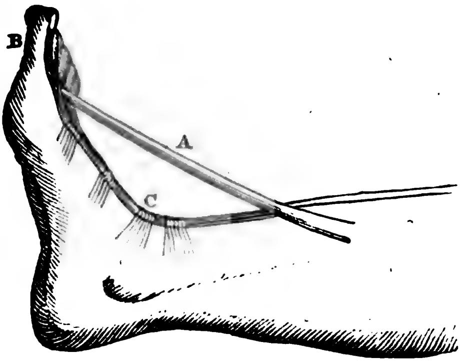
Insertion of Fibres into Tendon.

The largest angle, formed by the outer fibres of the deltoid, is estimated by Haller at 30°: the smallest about 8°. If this disadvantage

be taken into account, the deltoid will have to contract with a force equal to 1,284 pounds, to raise fifty-five pounds at the elbow. It is farther contended by Borelli, Sturm, and Haller, that the force of the muscle, as estimated in the preceding calculations, must be doubled, seeing that it has to exert as much force in resisting the bone which affords a fixed point at one extremity, as in elevating the weight at the other. This estimate, if admitted, would elevate the force, to be exerted by the deltoid in raising the fifty pounds, to 2,568 pounds. Lastly: Much force is spent when a muscle passes over many joints; antagonist muscles must, likewise, exert an influence of the kind, consuming a certain portion of the force developed in the contraction of the muscle.

On the other hand, there are arrangements that augment the power developed by muscles;—as the thick articular extremities of bones; the patella and sesamoid bones in general; all of which enlarge the angle, at which the tendon is inserted into the bone or lever. The projecting processes for muscular attachments, as the trochanters, protuberance of the os calcis, spinous processes of the vertebræ, &c., augment the arm of the lever, and are thus inservient to a like valuable purpose. The smoothness of the articular surfaces of bones,—tipped, as they are, with cartilage,—and the synovia, which lubricates the joints, by diminishing friction, as well as the bursæ mucosæ, which are interposed wherever there is much pressure or friction, also aids the power. Trochleæ or pulleys act only in directing the force, without augmenting its amount; and the same may be said of the bony canals and tendinous sheaths, by which the tendons of the muscles, especially those passing to the fingers and toes, are kept in their proper course. Still, it must be admitted, that, as regards the effort to be exerted by muscles, it must, in almost all cases, be much greater than the resistance to be overcome. The very fact of the lever of the third kind being that which prevails in our movements shows this. The mere mechanician has conceived this to be an unwise construction: and that there is a needless expense of force for the attainment of a determinate end. In all cases we find, that the expense of power has been but little regarded in the construction of the frame; nor is it necessary that it should have been. It must be recollected, that the contraction of the muscle is under the nervous influence, and that, within certain limits, the force, to be employed, is regulated by the influx sent by it into the muscle. The great object in the formation of the body appears to have been—to unite symmetry and convenience with the attainment of great velocity and extent of motion, so that whilst the power is moving through a small space, the weight or resistance shall move rapidly through one more extensive. We have seen that, in these respects, the lever of the third kind is most fitting. With the others less power might be required; but there would be less extent of motion and velocity, whilst the symmetry and convenience of the body would be destroyed. Suppose, for example, that in Fig. 179, the biceps—instead of being inserted at E, near the elbow—had passed on to the wrist,—or, to simplify the matter, to the extremity of the member; it would assuredly have acted with more force—the lever having been changed into one of the second kind,—but the hand would have lost that velocity and extent of motion, which are so important to

Fig. 181.



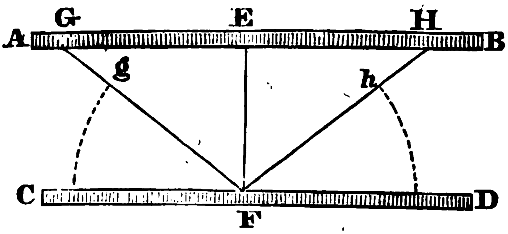
Tendon of the Great Toe.*

it; and the course of the muscle would have been so modified as to convert the convenient and symmetrical member into a cumbrous, webbed instrument, badly adapted for the multitudinous purposes to which it has to be applied.

The same effect results, as Sir Charles Bell[1] has remarked, from the course of tendons and their confinement by sheaths, strengthened by ligaments.' If the tendon A, Fig. 181, took the shortest course to its termination at B, it would draw up the toe with more force; but the toe would lose its velocity of movement.

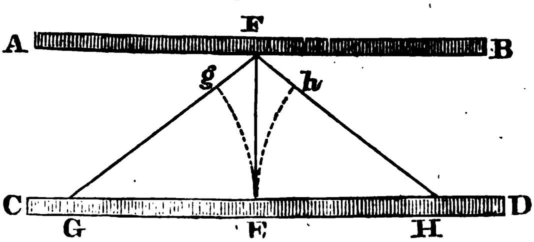
To favour this velocity, we find that the majority of muscles are inserted obliquely into their levers, and the fibres into the tendons. By this arrangement, as we have proved, considerable loss of power results; but in the majority of cases, the motion is effected by a less degree of decurtation than if the muscles were straight. Let A B and C D, Figs. 182 and 183, be parts of two ribs that are parallel, and continue parallel till brought into contact by the action of the straight muscle E F; or by that of the oblique muscles F G and F H. Now it is obvious, that when the point E comes in contact with F, the length of the straight muscle E F must be null; whilst that of the oblique muscles will only have experienced a decurtation equal to G g and H h, Fig. 182; and to F g and F h, Fig. 183. It is clear, also, that, in these cases, the straight muscles can never so con-

Fig. 182.



Action of Intercostal Muscles.

Fig. 183.



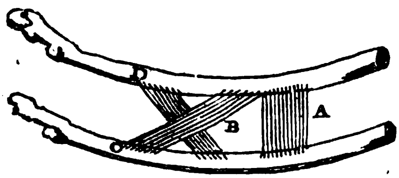
Action of Intercostal Muscles.

[1] Animal Mechanics, Library of Useful Knowledge, p. 27, Lond., 1829.

tract as to admit of a close approximation of the ribs; whilst the oblique muscles will admit of this to a much greater extent. We can, therefore, understand, why the intercostal muscles pass obliquely from one rib to another, as at D and B C, Fig. 184, instead of in a direction perpendicular to the two ribs as at A.

There are cases, however, in which a straight muscle may pass between two parallel ribs, and carry them through a given space, with less decurtation of fibres, than any oblique muscle, which has the same origin; but is inserted at a greater distance from the centre of motion, and acts through the medium of a longer lever. Moreover, a muscle, with a less degree of obliquity, may be so situate as to carry the bones through a given space, with a less decurtation of fibres than any other muscle having the same origin but a much greater degree of obliquity.

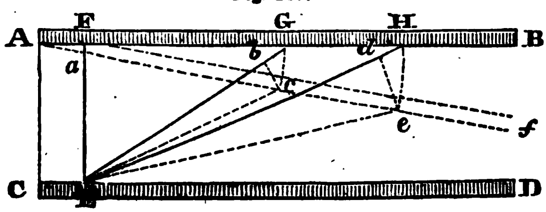
Fig. 184.



Action of Intercostals.

Suppose A B and C D, Fig. 185, to be two parallel ribs, of which A B is movable about A as a centre; and suppose it to be brought by the action of the straight muscle E F, and of the oblique muscles E G and E H, into the position A *f*. The points of insertion of the muscles will now be at *a*, *c*, and *e*, after having traversed the spaces F *a*, G *c*, and H *e*.

Fig. 185.

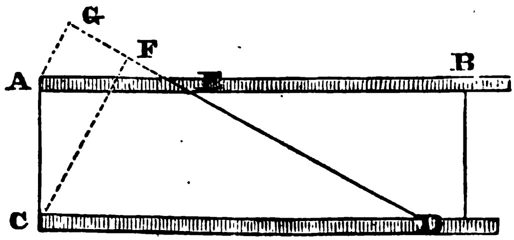


Action of Intercostals.

If we now, from the point E, as a centre, describe the arcs *c b* and *e d*; the spaces *d* H and *b* G will indicate the degree of decurtation, which the oblique muscles have experienced, and *a* F that of the straight muscle. This figure also shows, that when the muscles change the relative position of any two bones, they at the same time change the direction of their own action, and vary their lever. When the rib A B is brought into the position A *f*, the muscles E G and E H, by being brought down to *c* and *e*, have assumed the positions E *c* and E *e*; and have, consequently, changed their length, situation, obliquity, and leverage.

Again, of the muscles, which are attached to ribs that are parallel, equally movable, and situate at right angles to the spine, those which pass perpendicularly from one rib to the other will act upon each with equal leverage; and each will approach the other with the same velocity; whilst those that pass obliquely from one to the other, will make them approach with different velocities;—a principle which is strikingly applicable to the intercostal muscles. Let us suppose A B and C D, Fig. 186, to be two parallel ribs, articulated with the spine at A and C, and equally movable on these centres of motion. Let D B repre-

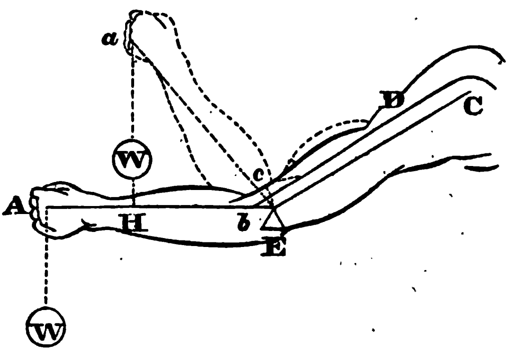
Fig. 186.



Action of Intercostals.

sent a straight muscle, passing directly from the one rib to the other; and D E an oblique muscle. The levers of D B, according to the mechanical principles laid down, will be A B and C D, perpendiculars drawn from the centres of motion to the line of direction of the power. These levers being parallel are of course equal; but the levers of D E will be C F and A G,—also perpendiculars drawn from the centres of motion to the line of direction of the power. These levers are of different lengths; and, accordingly, the muscle must act with different degrees of force on the two ribs; so that it will cause C D, on which it acts with the longest lever, to approach A B faster than it makes the latter approach the former,—in the ratio of C F to A C, or with three times the velocity.

Fig. 187.



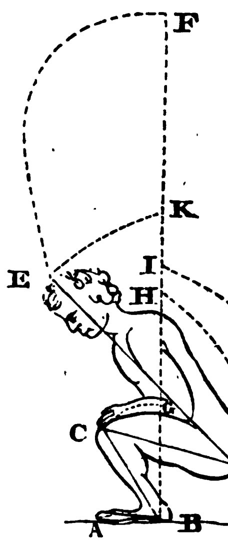
Action of Biceps.

In all muscular motions, the levers of the power and resistance are undergoing variations; so that the degree of power, necessary to be developed in one position of the member, may be much less than in another. The case of the biceps already referred to, elucidates this. Let E C, Fig. 187, represent the os humeri; E A the forearm; E the elbow-joint; W, a weight or resistance hung at the wrist, and D the biceps muscle, inserted at *b*, a tenth of the distance down the forearm. It is manifest, that the force, necessary for bending the arm, must be much greater when it is in the position A E than in that of E *a*. The lever of the resistance, in the former case, is the whole length of the forearm; or, in other words, the perpendicular drawn from the fulcrum to the line of direction of the weight W; but, when the arm is raised to *a*, the lever of the resistance is no longer E A, but E H: but not only is the lever of the resistance shortened; that of the power is augmented. The lever of the biceps, when the forearm is horizontal, is the dotted perpendicular drawn from the fulcrum at the elbow to the line of direction of the muscle; but when the forearm is bent to the position E *a*, the disposition of the muscle is also modified. It assumes the position occupied by the dotted

line, which is farther distant from the fulcrum; and the lever of the power is consequently increased. In this case, then, of the action of the biceps, in proportion as we raise the arm, the mechanical disadvantages become less and less; the lever of the power increasing, whilst that of the resistance diminishes.

In many of the changes of position of a body, whilst a bone is turning upon its centre of motion, the centre itself is often describing a curve at the same time. In Fig. 188, let A B represent the foot, B C the tibia, C D the thigh-bone, and D E the trunk; and let us suppose it is required to bring the body to the erect position B F; so that B C shall correspond to B G, C D to G I, and D E to I F. The point C will describe the curve C G; and, whilst it is accomplishing this, the point D is likewise moving; so that the latter, instead of describing the curve D H, which it would do, were the centre of motion C fixed, proceeds along the curve D I: the point E, again, is subjected to the like influence; and instead of describing the curve E K, which it would do if the centre D were fixed, rises along E F.

Fig. 188.



Combined Muscular Movements in Rising.

The motions produced by the muscles may be either simple or compound. The simple muscles admit of variety; some being straight, composed of parallel fasciculi; others reflected in their course, and others, again, are circular. In the straight muscles, each fibre, by its contraction, draws the tendon in its own direction; and the effect of the whole is to bring it towards the centre of the muscle. In a long muscle, the whole contractile effort is concentrated on the tendon, in consequence of the course of the fibres being parallel to that of the tendon. In most of the broad muscles, on the other hand, as the attachments at both extremities are usually at different points, all the fibres do not concur in one effort. Different sets of fibres may have a very different action from others, and are capable of being thrown separately into contraction. The ordinary direction in which a muscle acts is from its tendinous, back to its aponeurotic, attachment,—that is, from the movable to the more fixed part; and, in a straight muscle, this direction can be accurately appreciated. It must be borne in mind, however, that the muscle can act in an inverse direction also.

When the whole of the fibres composing a broad muscle are brought to act on the tendon, as in the case of the deltoid, we find, by the composition of forces, that the middle line of direction must be taken for the purpose of estimating their line of action. A part, however, may act and carry the arm upwards and outwards; whilst the opposite fibres may move it upwards and inwards.

Where a muscle is reflected, like the superior oblique of the eye, and

the peronei muscles,—the line of motion will be from the insertion to the point of reflection; precisely as a rope passing over a pulley raises the weight in a line drawn from the weight to the pulley.

The circular muscles, which have no precise origin or insertion, are inservient to the contraction of the apertures around which they are placed.

In executing the complex movements of any part of the frame, a combination of the action of the different muscles attached to the part, generally occurs,—rendering the process one of a complicated character. This, if no other cause existed, would render it extremely difficult to calculate the precise degree of force, which particular muscles, alone or in combination, are capable of exerting. The mathematical physiologists made multifarious attempts in this direction; but their conclusions were discrepant. When we bear in mind, that the force, capable of being exerted by any muscle, is dependent upon the proper organization of the muscle, and likewise upon the degree of energy of the brain, it will be apparent, that all attempts of the kind must be futile. We can determine with nicety the effect of which the parts are capable, supposing them inanimate structures. We can calculate the disadvantages, caused by the insertion of the power near the fulcrum; by the obliquity of the line of action of the power, &c.; but we have not the slightest data for estimating the effect produced by the nervous influx,—by that mysterious process, which generates a new force, and infuses it into the muscles, in a manner so unlike that in which the ordinary mechanical powers are exerted. The data necessary for such a calculation would be the precise influx from the brain,—the irritability of the muscle,—the mechanical influences, dependent on the straight or oblique direction of the fibres composing it, as regards the tendon,—the perpendicular or oblique direction in which the tendon is attached to the bone,—the particular variety of lever,—the length of the arm of the power and that of the resistance,—the loss sustained from friction, and the diminution of such loss caused by the cartilages that tip the bones, and by the synovia, &c.—data, which it is impossible to attain; and hence the solution of the problem is impracticable.

One great source of the combination of muscular motions is the necessity for rendering one of the attachments fixed, in order that the full force may be developed on the other. In but few of the muscles is the part, whence the muscle originates, steady. To these few, the muscles of the eye, which arise from the inner part of the orbit and pass forward to be inserted into the organ, belong. To show how distant muscles may be concerned in this fixation of one end of a muscle, when it is excited to the developement of plenary power, we may take the case of the deltoid, which arises from the scapula and clavicle, and is inserted into the os humeri: but the scapula and clavicle, themselves, are not entirely fixed; and, accordingly, if the deltoid were to contract alone, it would draw down the scapula and clavicle, as well as elevate the humerus. If, therefore, it be important to produce the latter effect only, the scapula and clavicle must be fixed by appropriate muscles; as by the rhomboidei, trapezius, &c. These muscles, however, arise from various vertebræ of the neck, which are themselves movable. It

becomes necessary, therefore, that the neck should be fixed by its extensors, which arise from the lumbar and dorsal regions. By the united action of all these muscles, the deltoid is able to exert its full effect in elevating the humerus. But the deltoid, like other muscles, is capable of acting inversely; as in the case of a person lying on the ground, and attempting to raise himself by laying hold of any object above him. The hand and forearm are thus rendered firm, and the deltoid now contracts from origin to insertion, and, consequently, elevates the scapula and clavicle. Again, if a person, in the recumbent posture, endeavours to bend the head forwards, the recti muscles of the abdomen are firmly contracted for the purpose of fixing the sternum, whence the sterno-cleido-mastoidei muscles in part arise, which can then exert their full power in bending the neck forwards. These instances will be sufficient to exemplify the mode in which muscular motions are combined. The same principle prevails over the whole body; and where a greater number of parts has to be moved, the case must, necessarily, be more complex.

When a part, movable in various directions, is drawn towards any point, it must be rendered steady, and be prevented from deviating, by the muscles on each side; and the extent of its motion may be partly regulated by the action of antagonist muscles. Supposing, for instance, that the head is inclined forwards, there must be muscles not only to move it in that direction, but also to prevent it from inclining to the right or left, and to limit the motion forwards; although doubt may arise, whether this be not entirely effected by the nervous influx sent by volition to the flexors of the head. Hence, some anatomists have considered, that there must, in these cases, be movers, directors, and moderators.

In sleep, the muscles are perhaps in the most complete state of relaxation; and, accordingly, this condition has been invoked, as affording evidence of the comparative preponderance of particular antagonizing muscles,—flexors and extensors, for example. In perfect sleep, when no volition is exercised over the muscles, the body reposes in a state of semiflexion,—which seems to show, that the flexor muscles have slightly the advantage over the extensors. M. Richerand[1] has assigned the following reasons for this preponderance. *First*. The number of flexors is greater than that of extensors. *Secondly*. The fibres, composing them, are more numerous and longer:—take, for example, the sartorius, gracilis, semi-tendinosus, semi-membranosus, and biceps, which are flexors of the leg, and the rectus and triceps cruris, which are its extensors. *Thirdly*. Their insertion is nearer the resistance and farther from the centre of motion, which adds to their force. *Fourthly*. Their insertion into the bones is at a larger angle, and nearer the perpendicular; and *Fifthly*. Their arrangement is such, that the continuation of the movement of flexion renders them perpendicular to the bones to be moved. The explanation, afforded by M. Richerand, applies, on the whole, to the case he has selected; but there are many exceptions to it. The

[1] Recueil des Mémoires de la Société Médicale de Paris, an vii. (1799), and Elémens de Physiologie, 13ème édit., par M. Bérard, ainé; édit. Belge, p. 253, § clx., Bruxelles, 1837.

extensors of the thigh, foot, and jaw, are decidedly predominant; and, according to M. Adelon,[1] experiments, instituted by Regnier with his dynamometer, make the extensors some kilogrammes more powerful than the flexors. In our various attitudes, the movements of the flexors certainly prevail largely; but as the power of contraction is regulated by volition, it is unnecessary to inquire, whether there be any physical predominance in the flexors over the extensors, as has been attempted by M. Richerand. We have already seen, that we can in no way attain a knowledge of the degree of force, which any one muscle of the body is capable of developing.

TABLE OF THE MUSCLES,

ARRANGED AFTER THE MANNER OF DR. BARCLAY, ACCORDING TO THEIR ACTIONS.

THE HEAD IS MOVED

Forwards by	*Backwards by*	*To either side by*
Platysma myoides,	Part of trapezius,	Platysma myoides,
Sterno-mastoideus,	Splenius capitis,	Sterno-mastoideus,
Rectus anticus major,	Complexus,	Part of trapezius,
" " minor,	Trachelo-mastoideus,	Splenius capitis,
Assisted (when the lower jaw is fixed) by	Rectus posticus major,	" colli,
Mylo-hyoideus,	" " minor,	Trachelo-mastoideus,
Genio-hyoideus,	Obliquus capitis superior.	Complexus.
Genio-hyo-glossus,		
Digastrici.		

THE NECK IS MOVED

Forwards by	*Backwards by*	*Laterally by*
Platysma myoides,	Part of trapezius,	Various combinations of those muscles which separately move it forwards and backwards, assisted by the scaleni, inter-transversales, and recti laterales.
Sterno-mastoideus,	Rhomboideus minor,	
Digastricus,	Serratus posticus superior,	
Mylo-hyoideus,	Splenius capitis,	
Genio-hyoideus,	" colli,	
Genio-hyo-glossus,	Complexus,	
Omo-hyoidei,	Trachelo-mastoideus,	
Sterno-hyoidei,	Transversalis colli,	
Thyro-hyoidei,	Inter-spinales colli,	
Rectus anticus minor,	Semi-spinales colli,	
Longus colli.	Rectus posticus major,	
	" " minor,	
	Obliquus capitis superior,	
	" " inferior,	
	Scaleni postici,	
	Levator scapulæ.	

THE TRUNK IS MOVED

Forwards by	*Backwards by*	*Laterally by*
Rectus abdominis,	Trapezius,	Obliquus externus,
Pyramidalis,	Rhomboideus major,	" internus,
Obliquus externus abdominis,	Latissimus dorsi,	Quadratus lumborum,
Obliquus internus,	Serratus posticus superior,	Longissimus dorsi,
Psoas magnus,	" " inferior,	Sacro-lumbalis,
" parvus,	Sacro-lumbalis,	Serrati postici,
Assisted (when the arms are carried forwards) by	Longissimus dorsi,	Latissimus dorsi.
Pectoralis major,	Spinales dorsi,	
" minor,	Semi-spinales dorsi,	
Serratus magnus.	Multifidus spinæ,	
	Inter-transversales dorsi et lumborum.	

[1] Physiologie de l'Homme, 2de édit., ii. 117, Paris, 1829; and art. Dynamomètre, in Dict. des Sciences Médicales.

THE SCAPULA IS MOVED

Upwards by	*Downwards by*	*Forwards by*	*Backwards by*
Trapezius, Levator scapulæ, Rhomboidei.	Lower part of trapezius, Latissimus dorsi, Pectoralis minor.	Pectoralis minor, Serratus magnus.	Part of trapezius, Rhomboidei, Latissimus dorsi.

THE HUMERUS IS MOVED

Forwards by	*Backwards by*	*Inwards by*	*Rotated inwards by*
Part of deltoid, Part of pectoralis major, *Assisted in some circumstances by* Biceps, Coraco-brachialis.	Part of deltoid, Teres major, " minor, Long head of triceps, Latissimus dorsi.	Part of pectoralis major, Latissimus dorsi.	Subscapularis, *Assisted occasionally by* Pectoralis major, Latissimus and teres major. *Outwards by* Supra-spinatus, Infra-spinatus, Teres minor.

THE FOREARM IS MOVED

Forwards by	*Backwards by*	*Rotated inwards by*
Biceps, Brachialis anticus, Pronator teres, *Assisted by* Flexor carpi radialis, " sublimis, " ulnaris, Supinator longus.	Triceps, Anconeus.	Pronator teres, Flexor carpi radialis, Palmaris longus, Flexor sublimis, Pronator quadratus. *Outwards by* Biceps, Supinator brevis, Extensor secundi internodii.

THE CARPUS IS MOVED

Forwards by	*Backwards by*	*Outwards by*	*Inwards by*
Flexor carpi radialis, Palmaris longus, Flexor sublimis, " carpi ulnaris, " profundus, " longus pollicis.	Extensor carpi radialis longior, Extensor carpi radialis brevior, Extensor secundi internodii, Indicator, Extensor communis digitorum, Extensor proprius pollicis.	Flexor carpi radialis, Extensor carpi radialis longior, Extensor carpi radialis brevior, Extensor ossis metacarpi, Extensor primi internodii.	Flexor sublimis, " carpi ulnaris, " profundus, Extensor communis digitorum, Extensor minimi digiti, Extensor carpi ulnaris.

THE THUMB IS MOVED

Inwards and forwards, across the palm, by	*Outwards and backwards by*	*Upwards and forwards, away from the other fingers, by*	*Backwards and inwards, to the other fingers, by*
Opponens pollicis, Flexor brevis, " longus.	Extensor ossis metacarpi pollicis, Extensor primi internodii, Extensor secundi internodii.	Abductor, *Assisted by part of the* Flexor brevis.	Adductor, Extensor primi internodii, Extensor secundi internodii.

THE FINGERS ARE MOVED

Forwards, or flexed, by	*Backwards, or extended, by*	*Outwards, to radial border, by*	*Inwards by*
Flexor sublimis, " profundus, Lumbricales, Interossei, Flexor brevis digiti minimi, Abductor digiti minimi.	Extensor communis, " minimi digiti, Indicator.	Abductor indicis, " digiti minimi, Interossei.	Abductor digiti minimi, Interossei.

THE THIGH IS MOVED

Forwards by	*Backwards by*	*Inwards by*	*Outwards by*
Psoas magnus,	Gluteus maximus,	Psoas magnus,	Tensor vaginæ femoris,
Iliacus,	Part of gluteus medius,	Iliacus,	Gluteus maximus,
Tensor vaginæ femoris,	Pyriformis,	Pectineus,	" medius,
Pectineus,	Obturator internus,	Gracilis,	" minimus,
Adductor longus,	Part of adductor magnus,	Adductor longus,	Pyriformis.
" brevis.	Long head of biceps,	" brevis,	
	Semi-tendinosus,	" magnus,	
	Semi-membranosus.	Obturator externus,	
		Quadratus femoris.	

THE THIGH IS ROTATED

Inwards by	*Outwards by*
Tensor vaginæ femoris,	Gluteus maximus,
Part of gluteus medius,	Part of gluteus medius,
And, when the leg is extended, by	Pyriformis,
Sartorius,	Gemellus superior,
Semi-tendinosus.	Obturator internus,
	Gemellus inferior,
	Quadratus femoris,
	Obturator externus,
	Psoas magnus,
	Iliacus,
	Adductor longus,
	" brevis,
	" magnus,
	Biceps cruris, slightly.

THE LEG IS MOVED

Backwards, or flexed, by	*Extended by*
Semi-tendinosus,	Rectus,
Biceps,	Crureus,
Semi-membranosus,	Vastus externus,
Gracilis,	" internus.
Sartorius,	
Popliteus.	

THE FOOT IS MOVED

Forwards, or flexed, by	*Backwards, or extended, by*	*Inclined inwards by*	*Outwards by*
Tibialis anticus,	Gastrocnemius,	Extensor proprius pollicis,	Peroneus longus,
Extensor proprius pollicis,	Plantaris,	Flexor longus digitorum,	" brevis,
Extensor longus digitorum,	Soleus,	Flexor longus pollicis,	Extensor longus digitorum,
Peroneus tertius.	Flexor longus digitorum,	Tibialis posticus.	Peroneus tertius.
	Flexor longus pollicis,		
	Tibialis posticus,		
	Peroneus longus,		
	" brevis.		

THE TOES ARE MOVED

Backwards, or flexed, by	*Forwards, or extended, by*	*Inclined inwards by*	*Outwards by*
Abductor pollicis,	Extensor longus digitorum,	Abductor pollicis,	Adductor pollicis,
Flexor brevis digitorum,	Extensor proprius pollicis,	Interossei.	" digiti minimi,
Abductor minimi digiti,	Extensor brevis digitorum.		Interossei.[1]
Flexor longus pollicis,			
" digitorum,			
" accessorius,			
Lumbricales,			
Flexor brevis pollicis,			
Adductor pollicis,			
Flexor brevis minimi digiti,			
Interossei.			

[1] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit. by Leidy, i. 465, Philadelphia, 1849.

ATTITUDES.

The attitudes, which man is capable of assuming, are of different kinds. They may, however, be reduced to two classes—the *active* and the *passive;* the former including those that require a muscular effort; and the latter comprising only one variety,—that in which the body is extended horizontally on the soil, and no effort needed to maintain its position.

We shall begin with the most ordinary attitude;—that of *standing on both feet.* This requires considerable muscular effort to preserve equilibrium. The base of sustentation—the space comprised between the feet plus that occupied by the feet themselves—is small; whilst the centre of gravity is high. The body, again, does not consist simply of one bone, but of many; all of which have to be kept steady by muscular effort; and it is necessary, that the vertical line shall fall within the base of sustentation, in order that equilibrium may be preserved.

That standing is the effect of the action of the different extensors is proved by the fact, that if an animal be killed suddenly, or stunned, so that volition is no longer exerted over the extensors, it immediately falls forward.

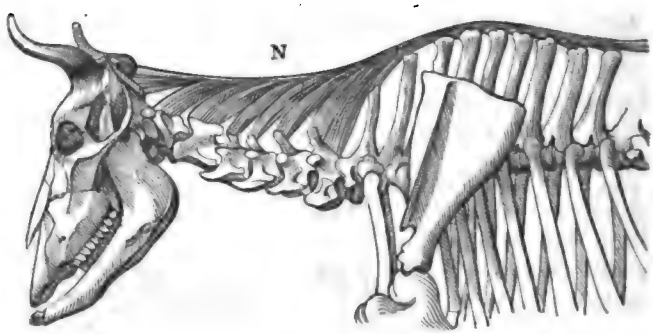
The head, which is intimately united with the atlas or first vertebra of the neck, forms with it a lever of the first kind; the fulcrum being in the articulation of the lateral parts of the atlas and vertebra dentata; whilst the power and the resistance occupy the extremities of the lever; and are situate—the one at the face, the other at the occiput. The fulcrum being nearer the occiput than to the anterior part of the face, the head has a tendency to fall forwards. This can be readily seen by supporting a skull on the condyles; yet Mr. Abernethy[1] affirms, that "the condyles are placed so exactly parallel in the centre of gravity, that when we sit upright, and go to sleep in that posture, the weight of the head has a tendency to *preponderate equally* in every direction, as we see in those who are dozing in a carriage"! In the living subject, the preponderance anteriorly is not so great as it is in the skeleton, because the greater part of the encephalon is lodged in the posterior portion; but the fact, that when we go to sleep in the upright position the head drops forward is sufficient evidence that it exists; and that in the waking state the head is kept in equilibrium on the vertebral column by the contraction of the extensor muscles of the head, which are situate at the back part of the neck, and inserted into the head;—as the splenius, complexus, trapezius, and posterior recti. These muscles are inserted perpendicularly into the lever or bone to be moved,—an advantage, and some compensation for the shortness of the arm of the lever by which they act.

In quadrupeds, the head not being in equilibrium on the spine these muscles are large and strong; the spinous and transverse processes of the vertebræ and the occipital depressions are larger; and, in addition,

[1] Physiological Lectures, exhibiting a general view of Mr. Hunter's Physiology, &c., Lect. 3, 2d edit., p. 115, London, 1822.

they have a strong ligament—*posterior cervical* or *ligamentum nuchæ*, (N, Fig. 189,)—which extends from the spinous processes of the vertebræ to the occiput, and aids in supporting the head.

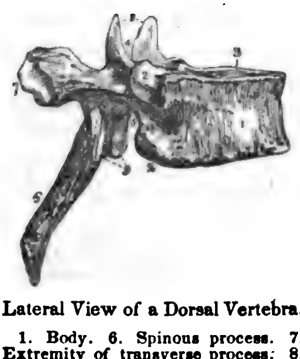
Fig. 189.



Ligamentum Nuchæ.

The vertebral column supports the head, and transmits the weight to its lower extremity. The tendency of the column is to bear forwards;—the upper limbs, neck, thorax with its contents, the greater part of the contents of the abdomen, and the head itself, by reason of its tendency to fall forwards, either directly or indirectly exert their weight upon it. Hence the necessity for its great firmness and solidity, which are readily appreciated, if we examine the mode of junction of the different vertebræ, with the strong, ligamentous bands connecting them, the whole having the form of a pyramid, whose base rests upon the sacrum, with three curvatures in opposite directions, which give it more resistance than if it were straight, and enable it to support very heavy burdens in addition to the weight of the organs pressing upon it. (Fig. 5, p. 77.) The tendency of the spine to fall forward is resisted by the extensor muscles, which fill the vertebral fossæ or gutters—sacrolumbalis, longissimus dorsi, multifidus spinæ, &c.—and pass from the sacrum to the lower vertebræ of the spine, and from the lower to the upper. Each vertebra, in this action, constitutes a lever of the first kind; the fulcrum of which is in the intervertebral cartilage; the power in the ribs, and other parts that draw the body forwards; and the resistance in the muscles attached to the spinous and transverse processes.

Fig. 190.



Lateral View of a Dorsal Vertebra.

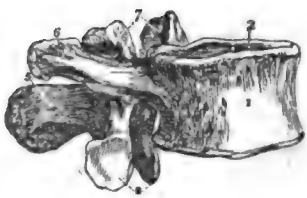
1. Body. 6. Spinous process. 7. Extremity of transverse process. 8. Superior articular processes. 9. Inferior articular processes.

The vertebral column, regarded as a whole, may be considered a lever of the third kind; the fulcrum of which is in the union between the last lumbar vertebra and sacrum, the power in the parts drawing the spine forward, and the resistance in the muscles of the back. It is on the lower

part of the lever that the power acts most forcibly; and it is there that the pyramid is thicker, and that the spinous and transverse processes are larger, and more horizontal. We can accordingly comprehend why fatigue should be experienced in the loins and sacrum, when we have been, for a long time, in the erect attitude. It need scarcely be said, that the longer and more horizontal the spinous processes, the greater will be the arm of the lever; and the less the muscular force necessary to produce a given effect.

The weight of the whole of the upper part of the body is transmitted to the pelvis; which, resting upon the thigh-bones as on pivots, represents a lever of the first kind, the fulcrum being in the ilio-femoral articulations; the power and resistance situate before and behind. The pelvis supports the weight of a part of the abdominal viscera; and the sacrum that of the vertebral column, which, by reason of its shape, transmits the weight equally to the ossa femorum, through the medium of the ossa ilii. When the pelvis is, therefore, in equilibrium on the heads of the thigh-bones, this is owing to many causes. The abdominal viscera, pressing upon the anterior part of the pelvis, which is naturally inclined forwards, tend to depress the os pubis; whilst the vertebral column by its weight tends to press down the sacrum. As the weight of the latter is more considerable than that of the former, muscles would seem to be required to keep it in equilibrium, as well as others passing from the femur to be inserted into the os pubis, by the contraction of which the excess of weight of the vertebral column may be counterbalanced. Such muscles do exist; but, as M. Magendie[1] remarks, they are not the great agents in producing the equilibrium of the pelvis on the thigh-bones; for the pelvis, instead of having a tendency to be depressed posteriorly, would appear to bear forwards, inasmuch as the muscles, that resist the tendency which the spine itself has to bear forwards, have their fixed point on the pelvis; and consequently exert a considerable effort to draw it upwards. The strong glutæi muscles, which form the nates, and are inserted into the os femoris, are the great agents of the equipoise; and as the hip-joint is nearer the pubis than it is to the sacrum, these muscles act with a greater leverage.

Fig. 191.



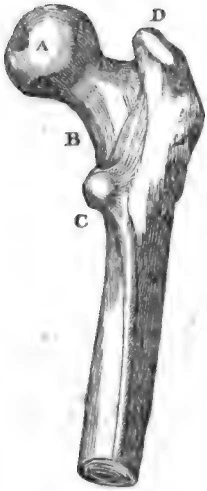
Lateral View of a Lumbar Vertebra.

1. Body. 5. Spinous process. 6. Transverse process. 7. Superior articular processes. 8. Inferior articular processes.

The thigh-bones transmit the weight of the trunk to the tibia; and here we see the advantage of the neck of the thigh-bone, which, as represented in Fig. 192, B, joins the shaft at a considerable angle. The trochanters D and C are for muscular attachments; and are, of course, advantageous to the muscles, which are inserted into them. The cervix femoris directs the head of the bone, A, obliquely upwards and inwards, so that, whilst it supports the vertical pressure of the pelvis, it resists the separation of the ilia, which the pressure of the sacrum, with its superincumbent weight, has a tendency to produce.

[1] Précis, &c., edit. cit., i. 296.

Fig. 192.



Upper Portion of Thigh-Bone.

But another and important advantage is that of affording additional strength in adventitious circumstances. When we are standing perfectly erect, the necks of the thigh-bones are very oblique, compared with the line of direction of the body; but if we are thrown forcibly to one side, the line of direction of gravitation corresponds more nearly with that of the neck of the thigh-bone, and fracture is rarely produced in this manner. The most common cause of fracture of the neck of the thigh-bone is slipping from a curbstone, or any slight elevation, with one foot, upon a firm substance beneath; and the fracture in such case, is generally transverse. The advantage of this arrangement of the neck of the thigh-bone has been compared not inaptly to that resulting from the *dishing* of a wheel; or the oblique position of the spokes from the nave outward to the felly, which strengthens the wheel against the strains produced by its sinking with force into a rut or other hollow.[1] The femur transmits the weight of the body to the large bone of the leg—the tibia; but, from the mode in which the pelvis presses upon it, its lower extremity has a tendency to bear forwards. This is prevented by the action of the extensors of the leg—rectus and triceps cruris—whose power is augmented by the presence of the patella—a sesamoid bone, seated behind their tendon. The muscles of the posterior part of the leg, which are attached to the condyles of the thigh-bone, aid also in preserving the equilibrium.

The tibia is the sole agent for the transmission of the superincumbent weight to the foot. Its upper extremity has, however, a tendency to bear forwards like the lower part of the os femoris. This is prevented by the contraction of the gastrocnemii, tibialis posticus, and other muscles on the posterior part of the leg.

The foot sustains the whole weight of the body; and its shape and structure are well adapted for the purpose. The sole has some extent, which contributes to the firmness of the erect attitude. The skin and epidermis are thick; and beneath the skin is a thick, adipous stratum, in greater quantity at the parts of the foot which come in contact with the soil. This fat forms a kind of elastic cushion, adapted for deadening or diminishing the effect of pressure. The whole of the sole of the foot does not come in contact with the ground. The weight is transmitted by the heel, the outer margin, the part corresponding to the anterior extremity of the metatarsal bones, and the extremities or pulps of the toes. The tibia transmits the weight to the astragalus; and from this bone it is distributed to the others that compose the foot; but the heel conveys the largest share. When the foot rests upon a flat surface, it is entirely passive; but when upon a slippery soil, the flexors of the toes, especially of the great toe, are firmly contracted, so

[1] See Fig. 170; also, Sir C. Bell, Animal Mechanics, p. 21, Library of Useful Knowledge, Lond., 1829.

as to fix the shoe, as far as possible, and render the attitude more stable. The use of shoes interferes largely with the exercise of the toes, which, in the savage, are capable of diversified and considerable action.

The use of the fibula is, to serve the purpose of a clasp, as its name imports. The tibia exerts its pressure chiefly towards the inner part of the foot, and, consequently, were it not for the fibula, which passes down below the articulation, dislocation outwards would be constantly menacing us. The fibula has no participation in the transmission of the weight to the ground.

The conditions for equilibrium, as applicable to man, have been already indicated. If the base of sustentation be rendered extensive in any one direction, as by widely separating the feet, the attitude is more firm in one direction, but less so in the other. It is as firm as possible in every direction, when the feet are turned forwards parallel to each other, and are separated by a space equal to the length of one. Whatever diminishes the base of sustentation, diminishes, in like proportion, the stability of the erect attitude. Hence the difficulty of walking on stilts or wooden legs, on the toes, tight rope, &c. It seems that the inhabitants of Les Landes,[1] in the south-west of France, are enabled by habit to use stilts with singular facility. The sandy plains, that bear this name, afford tolerable pasturage for sheep; but, during one part of the year, they are half covered with water; and during the remainder, they are very unfit walking ground, on account of the deep, loose sand, and thick furze. The natives, in consequence, habituate themselves to the use of stilts or wooden poles, the former of which are put on and off as regularly as parts of their dress. With these they walk readily over the loose sand or through the water, with steps eight or ten feet long. The difficulty, in this kind of progression, does not arise solely from the smallness of the base of sustentation, but from the greater height to which the centre of gravity is thrown, which renders the equilibrium unstable.

Standing on one foot is necessarily more fatiguing, as it requires the strong and sustained contraction of the muscles that surround the hip-joint, to keep the pelvis in equilibrium on the os femoris; especially as the body has a strong tendency to fall to the side that is unsupported. The muscles, that prevent the trunk from falling in this direction, are the glutæi, gemelli, tensor vaginæ femoris, pyramidalis, obturators, and quadratus femoris. The use of the neck of the thigh-bone and the great trochanter is here manifest. The base of sustentation, in this case, is the space occupied by the foot which is in contact with the soil; and it need hardly be said, that if this be still farther diminished, by attempting to stand on the toes, the attitude cannot be sustained.

In the *attitude on the knees*, the centre of gravity is brought lower, but the base of sustentation is smaller than on the feet. The patella has to bear the chief pressure; and as it is not provided with a fatty cushion such as exists at the sole of the foot, the position becomes painful, and the surface soon abraded. These remarks apply to the case, in which the knees only come in contact with the soil. When the feet

[1] Arnott, Elements of Physics, 3d Amer. edit., i. 15, Philad., 1835.

are allowed to touch also, by the points of the toes, the attitude is much more easy and firm, as the base of sustentation is largely augmented, and comprises the space between the knees and toes plus the space occupied by those parts.

The *sitting posture* admits of variety, and its physiology is easily intelligible. In every form in which the back is unsupported, the weight of the body is conveyed to the soil by the pelvis; and the broader this base the firmer the attitude. When we sit upon a stool without any back, and with the legs raised from the ground, the whole of the weight is conveyed by the parts in contact with the seat; but if the feet touch the ground, the weight of the lower extremities is transmitted to the soil by the feet, whilst the pelvis transmits that of the upper part of the body. In both cases, if the attitude be long maintained, fatigue is felt in the back, owing to the continued action of the extensor muscles in keeping the body erect. Sitting in an ordinary chair differs somewhat, in a part of the body being supported. Fatigue is felt in the neck, which is unsupported, and requires the sustained contraction of the extensor muscles of the head. To support all the parts, as far as possible, long-backed chairs have been introduced, which sustain the whole body and head; and, when they are provided with rockers, a position approaching to the easiest of all attitudes can be assumed. To produce a similar effect in a common chair, the body is often thrown back until the chair rests on its hinder legs only. When the feet of the individual are on the ground, this position is stable; the base of sustentation being large, and comprised between the legs of the chair and the feet of the individual, added to the space occupied by the parts themselves, that are in contact with the soil; but as soon as he raises his feet, the equilibrium is destroyed from the impracticability of making the vertical line fall within the base of sustentation, which is now reduced to the space occupied by the legs of the chair plus the space between them. In all the varieties of the sitting posture, equilibrium is facilitated by the centre of gravity being brought nearer to the ground.

Lastly. The *horizontal posture* is the only one that requires no muscular effort. Hence it is the attitude of repose, and of the sick and the feeble. The base of sustentation is here extremely large; and the centre of gravity very low. Accordingly, the attitude can be maintained for a long time; the only inconvenience being that which results to the skin from prolonged pressure on those parts that chiefly convey the weight to the bed,—as the back of the pelvis, the region of the great trochanter, &c.—an inconvenience, which attracts the attention of the physician, more or less, in all protracted and consuming maladies. The reason, why we prefer soft, elastic beds, is not simply to prevent abrasion of those parts of the body that are most exposed to pressure, but to enable a greater portion of the body to transmit the weight; and thus occasion a more equable partition of the pressure.

There are numerous other attitudes, which may be assumed; as, upon one knee, on the head, astride, &c.; but they do not need explanation,—their physiology being obvious after what has been said.

MOVEMENTS.

The movements, of which the body is susceptible, are of two kinds,—*partial* and *locomotive;* the former simply changing the relative situation of parts of the body; the latter the relation of the whole body to the soil. Many of the partial movements constitute an inherent part of the different functions, and are considered under them.

In the erect attitude, whilst the body holds the same correspondence with the soil, the position of the upper parts of the body may be greatly varied, provided the vertical line falls within the base of sustentation. Accordingly, to produce this effect, if the upper part of the body be inclined in one direction, the lower will have to be thrown more to the opposite.

The head may be turned forwards, backwards, or to one side; and it is capable of a rotatory motion to the right and left. The three first movements, when slight, occur in the articulation of the occipital bone and atlas; but if to a greater extent, the whole of the cervical vertebræ participate. The rotatory motion is effected essentially in the articulation between the first and second vertebræ; the latter of which has an arrangement admirably adapting it for this purpose. A toothlike or *odontoid* process arises from its anterior part, on which the posterior surface of the anterior part of the atlas or first vertebra turns as on a pivot. This arrangement has obtained the second vertebra the name *vertebra dentata*, and its function, that of *axis*. Rotation to the right is effected by the contraction of the left sterno-mastoid and splenius, and of the right complexus,—to the left by the action of the opposite muscles of the same name. The motions of the head aid the senses of sight, hearing, and smell; and are useful in the production of the different vocal tones, by occasioning elongation or decurtation of the trachea and vocal tube. They are, likewise, inservient to expression.

The spine, as a whole, and each of the vertebræ composing it, are capable of flexion, extension, lateral inclination, and circumduction. These motions occur in the fibro-cartilages between the vertebræ; and they are more easy and extensive, in proportion to the thickness and width of the cartilages. This is one cause why the motions of the cervical and lumbar portions of the vertebral column are freer than those of the dorsal. The *intervertebral substances* or *fibro-cartilages* possess a remarkable degree of elasticity. They yield somewhat, however, to prolonged pressure; and hence, after long continuance in the erect attitude, our stature may be sensibly curtailed. We can thus understand, that at night we may be shorter than in the morning. Buffon asserts, that the son of one of his most zealous *collaborateurs*, M. Guéneau de Montbeillard,—a young man of tall stature,—lost an inch and a half after having danced all night. The loss must be partly ascribed to the condensation of the adipous tissue beneath the foot. During the flexion of the spine, these cartilages are depressed on the side of the flexure, but they rise on the other; and, by their elasticity, are important agents in the restoration of the body to the erect position. Where they are thickest the greatest extent of motion is per-

mitted, and this is a cause why the spine admits of the greatest motion anteriorly. In rotation, the whole is pressed upon and undergoes elongation in the direction of its constituent laminæ. In old age, the cartilages become shrivelled; and this, with the loss of muscular power, is one of the causes why old people bend forwards.

When we assume different positions with the trunk, the centre of motion of the vertebræ becomes modified. If we bend forwards, it is thrown on the anterior part of the body of the vertebræ; if to one side, on the articulating processes, &c. Each vertebra, we have seen, is a lever of the first kind; and as the centre of motion becomes altered the leverage must be so likewise. It is when the body has been bent forwards, and the object is to restore it to the erect position, that the power acts with the greatest advantage,—the fulcrum being thrown to the anterior part of the body of the vertebra, and the arm of the power being the distance between this point and the extremity of the spinous process into which the power is inserted.

Each vertebra has but a slight degree of motion; but the sum of all their motions is considerable, and is estimated by multiplying the single motion by the number of vertebræ. The result, however, can only be regarded as approximate, as the extent of motion, of which the different vertebræ are capable, necessarily varies. The arrangement of the spinous processes of the vertebræ—especially of the *dorsal*—prevents any considerable flexion of the body backwards: and when we find the tumbler bending his body back until his head touches his heels, it is owing to the arrangement of the spine having been modified in early life by constant efforts of the kind, until there are no longer obstacles to the movement.

The motions of the vertebræ are frequently united to those of the pelvis on the thigh-bones, so that they seem to be more extensive than they really are. This is the case when we make a low bow.

The motions of the spine are inservient to those of the head, and of the superior and inferior extremities.

The upper limbs are capable of various motions; some of which have been already described; others will be hereafter. They are useful in the different attitudes; and, at times, by transmitting to the soil a part of the weight of the body, and thus enlarging the base of sustentation,—as when we employ a stick, rest on the hands and knees, or support the head on one or both elbows. They are of great use, likewise, in preserving equilibrium when we walk on a very narrow base; serving in part the purpose of the pole employed by the dancer on the tight-rope.

The lower extremities are, of course, locomotive organs; but they are susceptible of partial movements likewise; as when we kick with one foot, try the consistence of the ground, cross the legs, tread the foot-board of a lathe, &c.

Thus much for the attitudes. We shall now consider the mode in which the relation of the body to the soil is altered, comprising the physiology of walking, leaping, running, swimming, flying, &c., which constitute the different varieties of locomotion or progression.

LOCOMOTIVE MOVEMENTS.[1]

a. *Walking.*

Walking is motion on a fixed surface, the centre of gravity being alternately moved by one of the extremities and sustained by the other, without the latter being, at any time, completely off the ground. It consists of a succession of steps, which are effected—in the erect attitude and on a horizontal surface—by bending one of the thighs upon the pelvis and the leg upon the thigh, so as to detach the foot from the ground by the general decurtation of the limb. The flexion of the limb is succeeded by its being carried forward; the heel is then brought to the ground, and, successively, the whole of the inferior surface of the foot. If the bones of the leg were perpendicular to the part which first touches the ground, we should experience a jolt; but, instead of that, the foot descends in an arc of a circle, the centre of which is the point of the heel.

Fig. 193.

Movement of the Foot in Walking.

In order that the limb shall be thus carried forward, the pelvis must have described a movement of rotation on the head of the thigh-bone of the limb that has not been moved, and must have carried forward the corresponding side of the body. As yet, only one limb has advanced. The base of sustentation has been modified, but there has been no progression. The limb, remaining behind, has now to be raised and brought forward, so as to pass the other, or to be on the same line with it, as the case may be; and this finishes the *step.* In order to bring up the limb that is behind, the foot must be successively detached from the soil, from the heel to the toe. In this way, an elongation of the limb is produced, which assists in advancing the corresponding side of the trunk, and excites the rotation of the pelvis on the head of the thigh-bone first carried forward. A succession of these movements constitutes walking; the essence of which consists in the heads of the thigh-bones forming fixed points, on which the pelvis turns alternately, as upon a pivot, describing arcs of circles, which are more extensive in proportion to the size of the steps.

Walking in a straight line requires that the arcs of circles described by the pelvis, and the extension of the limbs when carried forward, shall be equal; otherwise, the body will be directed towards the side opposite to that of the limb whose movements are more extensive. Without the aid of vision, it would be impracticable for us to make the arcs equal, or to walk straight forward.

Walking backwards differs somewhat from this. The step is com-

[1] On the whole subject of Animal Motion, Animal Dynamics, Locomotion, or Progressive Motion of Animals, see an elaborate article by J. Bishop, in Cyclopædia of Anatomy and Physiology, Part xxiii. p. 407, London, April, 1842, and Prof. E. Weber, Art. Muskelbewegung, in Wagner's Handwörterbuch der Physiologie, 15te Lieferung, s. 1, Braunschweig, 1846.

menced by bending the thigh upon the pelvis, and, at the same time, the leg upon the thigh. The extension of the thigh on the pelvis succeeds, and the whole limb is carried backward; the leg is afterwards extended upon the thigh, the point of the foot is brought to the ground, and the remainder of its under surface in succession. The other foot is then raised on its point, by which the corresponding limb is elongated; the pelvis, being pushed backwards, makes a rotation on the limb which is behind, and is, by the action of appropriate muscles, carried on a level with, or behind, the other, to afford a new pivot in its turn. Walking laterally is different from the two last in no arcs being described. In this case, one of the thighs is first slightly bent upon the pelvis, in order to detach the foot from the ground; the whole limb is then moved away by the action of the abductors, and is brought down to the ground. The other limb follows.

If we walk up hill, the fatigue is much augmented; because the flexion of the limb, first carried forward, has to be more considerable; and the limb, that remains behind, has not only to cause the pelvis to execute the movement of rotation, but it has to raise the whole weight of the body, in order to transport it upon the limb which is in advance. To aid in throwing the weight forward, the body is bent forward, so that the centre of gravity may be as favourably disposed as possible; and the extensor muscles of the leg carried forward are powerfully contracted to raise the trunk; hence, the feeling of fatigue, which we experience in the knee and anterior part of the thigh, on ascending a long flight of stairs. Fatigue is likewise felt in the calf of the leg, on account of the strong efforts developed in extending the foot, and projecting the body forward. Walking down hill is more fatiguing than on level ground. In this case, there is a tendency in the body to fall forward; great effort is, consequently, required to keep the vertical line within the base of sustentation; and, accordingly, the muscles, employed in the extension of the head and vertebral column, experience fatigue.

In all these kinds of progression, the character of the soil is a matter of importance. It must be firm enough to afford support to the limb that presses upon it, otherwise fatigue is experienced, and progression slow and laborious. This occurs, whenever the soil is too soft or too smooth; the former yielding to the foot, and the latter presenting no inequalities to which the foot can attach itself. The soil, too, has some influence, in particular cases, by virtue of its elasticity. Such, at least, is the opinion of Borelli;[1] but Barthez[2] thinks, that the influence of the soil is limited to the degree in which it furnishes a firm support. If the soil, again, be movable, as the deck of a vessel, the line of gravity is apt to fall outside the base of sustentation; and to avoid this, the base is enlarged by separating the legs so as to give a characteristic air to the gait of the mariner;—and, lastly, if the base be very narrow, as on the tight-rope, the steps are obliged to be rapid, and the arms are aided in modifying the centre of gravity as may be required, by the use of a long and heavy pole.

[1] De Motu Animalium, &c., Lugd. Bat., 1710.
[2] Nouveaux Elémens de la Science de l'Homme, Paris, 1806.

b. *Leaping.*

In the action of leaping, the whole body is raised from the ground; and, for a short period, suspended in the air. It consists, essentially, in the sudden extension of the limbs, after they have undergone an unusual degree of flexion. Leaping may be effected directly upwards, forwards, backwards, or laterally.

In the ordinary case of the vertical leap, the head is slightly bent on the neck; the vertebral column curved forwards; the pelvis bent upon the thigh; the thigh upon the leg; and the leg upon the foot; the heel generally pressing lightly on the soil, or not touching it at all. This state of general flexion is suddenly succeeded by a quick extension of all the bent joints; so that the different parts of the body are rapidly elevated, with a force surpassing their own gravity, and to an extent dependent upon the force developed. In this general muscular movement, the muscles that form the calf of the leg, and are inserted into the heel, have to develope the greatest force, inasmuch as they have to raise the whole body, and to give it the impulse, which surmounts its gravity. They are, however, favourably circumstanced for the purpose;—being remarkably strong; inserted perpendicularly into the heel; and having the advantage of a long arm of a lever. Figure 188 will show, that whenever the body is bent in the position it assumes preliminary to a leap, opposite impulses must be communicated by the restoration of the different parts to the vertical line B F. The leg B will tend to impel the body backwards, by following the curved line C G. C D, on the other hand, by describing the curve D I, will tend to impel it forward; whilst the head and trunk, represented by the line D E, will describe the curve E F, and give an impulse backward. Every vertical leap must, therefore, be a mean between these different impulses, or rather the backward and forward impulses must destroy or neutralize each other; and that which is concerned in the elevation of the trunk be alone effective.

In the forward leap, the movement of rotation of the thigh predominates over the impulses backward, and the body is projected forward. On the other hand, the impulses of the vertebral column, and of the leg on the foot, prevail in the backward leap. The length of the lower limbs is favourable to the extent of the leap. The forward leap, in particular, is greatly dependent upon the length of the femur, in which the forward impulse is situate. It does not appear, that any kind of impulse is communicated to the body, at the moment of leaping, by the surface on which we rest, unless it be very elastic. In this last case, however, its reaction is added to the effort of the muscles, that occasion the elevation of the body; hence, the wonderful leaps of the performers in circuses and on the tight-rope. On the other hand, if the soil does not afford the necessary resistance, and yields to the feet, leaping is almost or wholly impracticable.

The upper extremities are not without their use in leaping. They are brought close to the body, whilst the joints are bent, and are separated from it at the moment when the body leaves the ground. By being held firmly in this manner, they allow the muscles, that pass from

the os humeri to the trunk, to exert a degree of traction upwards, and thus to assist the extensors of the feet in the projection of the body. It is with this view, that the ancients employed their ἁλτῆρες, or *poisers* in leaping; and that the moderns use bricks, stones, or other solid heavy bodies with a like intent. It is likewise manifest, that by steadying the arms, and then moving them rapidly backwards, a backward impulse may be given to the upper part of the trunk.

The effect of a run before we leap is to add to the force developed by muscular contraction that of the impulse acquired by the body whilst running. The leap is, under such circumstances, necessarily more extensive.

Some of the smaller animals surprise us by the extent of their leaps. The *jumping maggot*, found in cheese, erects itself upon its anus, forms its body into a circle, by bringing its head and tail into contact, and, having contracted every part as much as possible, unbends with a sudden jerk, and darts forward to an astonishing distance. Small animals leap much farther than the larger in proportion to their size; and, as Mr. Sharon Turner has remarked,[1] "exhibit muscular powers still more superior to those of the greatest animals than their comparative minds." He has given amusing representations of this difference: for example, Linnæus observes, that if an elephant were as strong in proportion as a stag beetle, he would be able to tear up rocks and level mountains. A cock-chafer is, for its size, six times as strong as a horse.[2] The flea and locust leap two hundred times their own length, as if a man should leap three times as high as St. Paul's.[3] The cuckoo-spit froghopper sometimes leaps two or three yards, which is more than two hundred and fifty times its own length, as if a man should vault at once a quarter of a mile.[4] Mouffet[5] relates, that an English mechanic made a golden chain as long as a finger, with a lock and key, which was dragged by a flea; and Latreille[6] mentions a flea of moderate size dragging a silver cannon on wheels, that was twenty-four times its own weight. This cannon was charged with powder and fired, without the flea seeming to be alarmed.

c. *Running.*

This variety of progression consists of a series of low leaps performed by each leg in alternation. It differs from walking, in the body being projected forward at each step, and in the hind-foot being raised before the fore-foot touches the ground. It is more rapid than the quickest walk, because the acquired velocity is preserved and increased, at each bound, by a new velocity. Running, therefore, cannot be instantaneously suspended, although a stop may be put to walking at any moment.

In running, the body is inclined forward, in order that the centre of gravity may be in a proper position for receiving an impulse in that

[1] Sacred History of the World, Amer. edit., p. 372, New York, 1832.
[2] Kirby and Spence, Introduction to Entomology, Amer. edit., p. 486, Philad., 1846.
[3] Nat. History of Insects, i. 17.
[4] Insect Transformations, v. 6, p. 179
[5] Theatr. Insect., 275.
[6] Nouv. Dict. d'Histoire Natur., xxviii. 249, and Kirby, op. cit.

direction from the hind-leg; and the fore-leg is rapidly advanced to keep the vertical line within the base of sustentation, and thus prevent the body from falling. There is, consequently, in running, a moment in which the body is suspended in the air.

d. *Swimming.*

Although M. Magendie[1] affirms that the human body is, in general, specifically heavier than water; and that consequently, if left to itself in a considerable quantity of that fluid, it would sink to its lowest portion, the question respecting its specific gravity has not been rigorously determined; and many eminent practical philosophers have even held an opinion the reverse of that of Magendie. Borelli[2] accords with him; and a writer of a later period, Mr. Robertson,[3] who details a set of experiments on this subject, seems to have originally coincided with him also. He weighed, however, ten different individuals in water, comparing the weight with that of the fluid displaced by their bodies; and he affirms, that, with the exception of two, every man was lighter than his equal bulk of water, and much more so than his equal bulk of sea water;—"consequently," he says, "could persons, who fall into water, have presence of mind enough to avoid the fright usual on such accidents, many might be preserved from drowning." In corroboration of this inference, Mr. Robertson relates a circumstance connected with his own personal knowledge. A young gentleman, thirteen years of age, little acquainted with swimming, fell overboard from a vessel in a stormy sea; but having had presence of mind enough to turn immediately upon his back, he remained a full half hour, quietly floating on the surface of the water, until a boat was lowered from the vessel. He had used the precaution to retain his breath whenever a wave broke over him, until he again emerged.

A case is given in the Rev. Mr. Maude's *Visit to Niagara*, in 1803, which is corroborative of Mr. Robertson's view of this matter. The author was on board a sloop on Lake Champlain, when a boy, named Catlin, who was on deck cutting bread and cheese with a knife, was knocked overboard by the captain jibbing the boom. He missed catching hold of the canoe, which was dragging astern, and an attempt of Mr. Maude's servant to untie or cut the rope, which fastened it, that it might drift to his assistance, also failed. Catlin was known to be unable to swim. It was in the night and very dark, and it was with difficulty that the captain, who considered that there was no hope of saving his life, was at last prevailed upon to go in the canoe to attempt it. He succeeded, however, in picking the boy up, and brought him on board again in about a quarter of an hour. "Catlin's relation," proceeds Mr. Maude, "almost exceeds probability. He had heard my exclamation to seize the canoe, which he was on the point of doing, when it gave a sudden swing and baffled him; but, finding he could support his head above water, he dismissed all fear, expecting that the canoe would come every moment to his assistance. When he no longer

[1] Précis Elémentaire, i. 333. [2] De Motu Animalium, c. 23, de Natat. Prop., 217.
[3] Philos. Transact., vol. l.; also, Dr. Dalton, in Manchester Memoirs, vol. x.

heard our cheers from the sloop, hope began to fail him, and he was on the point of resigning himself to a watery grave, when he heard the captain's life-restoring voice. On telling Catlin that we despaired of his safety, as we understood that he could not swim, he replied: 'Nor can I. I was never before out of my depth; but I am fond of bathing, and have often seen lads what they call tread the water; that's what I did.' The truth of this account was made manifest, by the boy not only retaining his hat on his head, but its being perfectly dry; and what adds to the singularity of this event, the boy never quitted his grasp of the knife that he was eating his bread and cheese with."

Mr. Knight Spencer found, that he was buoyant on the surface of the sea, even when he held stones, weighing six pounds avoirdupois, in his hands. In the water, however, the stones lost two pounds five ounces in weight, so that he was really freighted with no more than three pounds eleven ounces. He himself weighed one hundred and thirty pounds.[1] Dr. Franklin,[2] whilst he considered the detached members of the body, and particularly the head, as of greater weight than their bulk of water, acknowledged the body in the aggregate to be of less specific gravity, by reason of the hollowness of the trunk. He thought, that a body immersed in water would sink up to the eyes, but that if the head were inclined back, so as to be supported by the water, the mouth and nostrils would remain above,—the body rising one inch at every inspiration, and sinking one inch at every expiration; and also, that clothes give additional weight in the water, although, in stepping out of it, the case is quite otherwise. He concluded, therefore, that if a person could avoid struggling and plunging, he might remain in the posture described with safety. That the body is to a certain degree buoyant, he refers to the experience of every one who has ever attempted to reach the bottom of deep water,—the effort required sufficiently proving that something resists our sinking.

The truth would appear to be, that there is only a slight difference between the specific gravity of the human body and that of water; the former being something greater, otherwise there would be no reason why the dead body should sink to the bottom, as it is known to do. It would seem, however, where the deposition of fat is excessive, the body may be of less specific gravity than water.[3] The old notion was, that, in the living state, the specific gravity of the body is decidedly less; but that, in death from drowning, a quantity of water always enters the lungs and stomach, and thus these cavities being no longer occupied with air, buoyancy is lost and the body sinks. Nothing is now better established than that no water gets into the stomach, except what is accidentally swallowed during the struggling; and that no water must be looked for in the lungs; a quantity of frothy mucus being all that is generally perceptible there. Yet, in courts of justice, the absence of water in these situations has been looked upon as evidence, where a body has been found in the water, that death had not occurred from drowning; and attention has consequently been directed

[1] Fleming's Philos. of Zoology, vol. i., Edinb., 1822.
[2] Works, iii. 374, Philad., 1808; and Sparks's edit., vi. 289, Boston, 1838.
[3] See vol. ii., under ADIPOUS EXHALATION.

to other causes, which might have produced it; the presumption being, that the person had been first killed, and then thrown into the water for the purpose of averting suspicion.

Another erroneous opinion, at one time prevalent, was, that if a person be thrown alive into water he will sink; if dead, he will swim; and, therefore, it is necessary, that some weight should be attached to a body, when committed to the deep, to make it sink. All these fallacious notions are dwelt upon in a case, full of interest to all jurists, medical and others;—that of Spencer Cowper, Esq., a member of the English bar, and afterwards one of the judges of the Court of Common Pleas, who, with three other individuals, was tried at Hertford Assizes, in 1699, for the murder of Mrs. Sarah Stout.[1] The speeches of the counsel, with the evidence of many of the medical witnesses, sufficiently testify the low condition of medico-legal knowledge at that period.[2] Mr. Jones—the counsel for the prosecution—affirmed, that "when her (Mrs. Stout's) body came to be viewed, it was very much wondered at; for, in the first place, it is contrary to nature, that any persons, that drown themselves, should float upon the water." "We have sufficient evidence," he adds, "that it is a thing that never was: if persons go alive into the water, then they sink; if dead, then they swim." In confirmation of this strange opinion, two seamen were examined, one of whom deposed as follows:—"In the year '89 or '90, in Beechy fight, I saw several thrown overboard during the engagement, but one particularly I took notice of, that was my friend and killed by my side. I saw him swim for a considerable distance from the ship, &c. Likewise in another engagement, where a man had both his legs shot off and died instantly, they threw over his legs; though they sunk, I saw his body float; likewise I have seen several men, who have died natural deaths at sea; they have, when they have been dead, had a considerable weight of ballast made fast to them and so were thrown overboard; because we held it for a general rule that all men swim if they be dead before they come into the water, and, on the contrary, I have seen men when they have been drowned, that they have sunk as soon as the breath is out of their bodies," &c. The weights are, however, attached to the dead, when they are thrown into the sea, not for the purpose of facilitating their descent, but to prevent them from rising, when putrefaction renders them buoyant, by the disengagement of air in the splanchnic cavities. On the same trial, Drs. Coatsworth, Burnet, Nailor, and Woodhouse deposed, that when a person is drowned, water will be taken into the stomach and lungs; and as none was found in the case of Mrs. Stout, they were of opinion, that she came to her death by other means.

From all that has been said, it would appear, that the great requisite for safety to the inexperienced who may fall accidentally into the water is a firm and sufficient conviction of the fact, that the living body naturally floats, or that it can be easily made to do so. This conviction being acquired, no more than a common share of presence of mind

[1] Hargrave's State Trials, vol. v.; Beck's Medical Jurisprudence, 6th edit., ii. 205, Albany, 1838.

[2] Lives of the Lord Chancellors, by Lord Campbell, Amer. edit., iv. 240, Philad., 1848.

would seem to be necessary to insure, that the portion of the body, which is the great outlet of the respiratory organs, shall be above the surface.

The movements, adapted to the progression of the body, are to be acquired in the same manner as a child learns to walk; proficiency in this, as in every thing else, being the result of practice.

Swimming nearly resembles leaping, except that the effort in it does not take place from a fixed surface. Both the upper and lower extremities participate in it. Whilst the former are brought to a point anterior to the head, and form a kind of cut-water, the lower extremities are drawn up, and suddenly extended, as in leaping. The water, of course, yields to their impulse; but not as rapidly as it is struck, and hence the body is projected forwards. The upper limbs are now separated, and carried circularly and forcibly round to the sides of the body, by which the impulse is maintained; the legs are in the meantime drawn up; and, by a succession of these movements, progression is effected—the hands and feet being turned outwards to present as large a resisting surface as possible. The chest is, at the same time, kept dilated, to augment the bulk of the body, and, of course, to render it specifically lighter, and the head is raised above the surface to admit of respiration. This action is analogous to that of the propulsion of a boat by oars. The body resembles the boat; and the upper and lower extremities are the oars or sculls.

The practised swimmer can execute almost as many movements in the water as he can on land.

e. *Flying.*

If the human body sinks in the water, how little can it be susceptible of suspension in the air by its own unassisted muscular powers! This is a mode of progression which is denied to man; and accordingly, most of the attempts at flying, since the mythical exploits of Dædalus and Icarus, have been confined to enabling the body to move from one place to another by means of ropes and appropriate adjuncts. Years ago, a native of this country exhibited a curious variety of progression, at Dover, England. He was called the "*flying phenomenon;*" and his plan, so far as we can recollect, was to have a rope extending from the heights to the beach beneath, along which he descended by means of rings attached to different parts of his person, which had the rope passing through them.

The sources of difficulty, in flying, are;—the great weight of the body, and the insufficient force which the muscles are capable of exerting. It is by no means impossible, however, that by some contrivance, of which the lightest gases might form a part, and by an imponderous apparatus, which would enlarge the surface of the upper extremities, progression, in this manner, might be effected;—but to a limited and unmanageable extent only.

f. *Other Varieties of Muscular Action.*

Connected with this subject we may refer briefly to some varieties of muscular action, the nature of which will be easily intelligible.

In *bearing a load*, we have simply a variety of walking in the erect attitude, with this addition, that the extensor muscles of the head, neck, or back,—according to the part on which the burden may be placed,—have to contract forcibly to support it. The position of the individual has, also, to be so regulated, that the centre of gravity shall always be over the base of sustentation. Hence, if the load be on a man's back, he leans forward; if borne before him, he leans backward; and this is the cause of the portly and consequential appearance of the corpulent. If the load be on his head he stands as upright as possible, for a like reason.

In *propelling a body* forwards, either by the hands or shoulders, the feet are firmly fixed on the ground; the limbs are in a state of semi-flexion, and the centre of gravity is directed forward, so as to aid the force that has to be developed by the muscles. The limbs are then suddenly extended; the body is thrown forward, and the whole power exerted on the obstacle which has to be moved.

On the other hand, when we *drag a weight* after us, or attempt to *dislodge a stake* from the earth, the feet are equally fixed firmly on the ground, but the body is in a state of extension, and is directed as far as practicable backwards, in order that the tendency to fall, owing to the centre of gravity overhanging the base of sustentation, may aid the force that has to be developed by the flexor muscles of the arms, which are then powerfully contracted, and the whole force is exerted upon the object. As, in both these cases, there is danger of falling should the body yield suddenly, the feet are so placed as to obviate this, as far as possible, by being separated in the direction in which the force is exerted.

Squeezing consists in laying hold of the object, either between the arms and body, or by the fingers; and then forcibly contracting the flexor muscles. In all these, and other varieties of strong muscular contraction, the respiration is interrupted, in order that the thorax may be rendered fixed, and serve as an immovable point of origin for the muscles of the head, shoulders, and arms. This is effected by taking in a full inspiration; strongly contracting the respiratory muscles, and, at the same time, closing the glottis to prevent the exit of the air.

Lastly: as organs of *prehension*, the upper extremities are of admirable organization, possessing great mobility, and at the same time solidity. The joint at the shoulder allows of extensive motion; and the bones, to which the arm is attached at this joint—scapula and clavicle—are themselves movable. The forearm is likewise susceptible of various movements on the arm, of which those of pronation and supination are not the least important; whilst the hand possesses every requisite for an organ of prehension. It is composed of numerous bones, and is capable of being applied to the most irregular surfaces. The great superiority of the human hand arises from the size and strength of the thumb, which can be brought into a state of opposition to the fingers; and is, therefore, of the highest use in enabling us to seize hold of, and grasp spherical bodies; to take up any object; to lay firm hold of whatever we seize, and to execute the various useful,

and ornamental processes of the arts. These processes require the most accurate, quick, and combined movements of the muscles. How quick, for example, is the motion of the hand in writing, and in executing the most rapid movements on the piano-forte! How accurate the muscular contraction, which stops the precise part of the violin-string to bring out the note or semi-tone in *allegro* movements; and what a multitude of combinations must be invoked in all these cases!

As an organ of touch, the advantages of the upper extremity have already been depicted; and much of what was then said applies to it as an organ of prehension. "In this double respect," observes M. Adelon,[1] "man is the best provided of animals. How much, in fact, does he stand in need of an ingenious instrument of prehension! As we have several times remarked, he has, in his organization, neither the offensive nor defensive arms, that are bestowed on other animals. Naked from birth, and exposed to the inclemencies of the atmosphere, without means of attack or defence against animals, he must incessantly labour to procure what he requires. It was not, consequently, enough that he should possess an intellect, capable of making him acquainted with, and of appropriating to himself, the universe. He must have an instrument adapted for the execution of all that his intellect conceives. Such instrument is his upper extremity. In short, whilst other animals find every thing in nature—necessary for their different wants—more or less prepared; man, alone, is obliged to labour to procure what he requires. He must make himself clothes, construct his habitations, and prepare his food. He is the *labouring* and *producing* animal *par excellence;* and hence needs not only an intellect to conceive, but an instrument to execute."

FUNCTION OF EXPRESSION OR LANGUAGE.

Under this head will be included those varieties of muscular contraction, by which man and animals exhibit the feelings that impress them, and communicate the knowledge of such feelings to each other. It comprises two different sets of actions:—those addressed to the ear—or phenomena of *voice:* and those appreciated by the senses of sight and touch—or *gestures*. Of these we shall treat consecutively.

a. *Of the Voice.*

By the term *voice*—or *phonation*, a term proposed by Chaussier—is meant the sound produced in the larynx, whilst the air is passing through it, either to enter, or issue from, the trachea.

1. ANATOMY OF THE VOCAL APPARATUS.

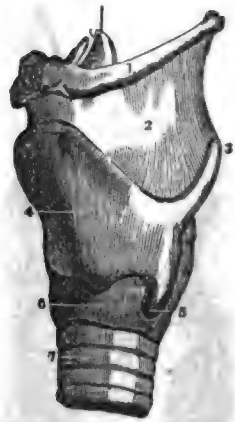
The apparatus, concerned in the production of voice, is composed, in man, of the muscles concerned in respiration; the larynx; the mouth and nasal fossæ. The first are merely agents for propelling the air through the instrument of voice. They will fall under consideration under Respiration; whilst the anatomy of the mouth and nasal fossæ has been, or will have to be, described in other places. The larynx,

[1] Physiologie de l'Homme, ii. 201, 2de édit., Paris, 1839.

and its primary dependencies, which are immediately concerned in the production of voice, will alone engage us at present.

The larynx is situate at the anterior part of the neck, and forms the projection so perceptible in that of the adult male, called *pomum Adami.* An attentive examination of the various parts which compose it, so far as they concern its physiological relations, will be necessary. This will exhibit the imperfect knowledge of several writers on the voice, and the false and insufficient views that have been entertained on the subject.

Fig. 194.



Lateral View of the Larynx.

1. Os hyoides. 2. Thyreo-hyoid ligament. 3. Cornu majus of thyroid cartilage. 4. Its angle and side. 5. Cornu minus. 6. Lateral portion of cricoid cartilage. 7. Rings of trachea.

If we look along the larynx from the trachea of which it is a continuation, we find that the tube becomes gradually narrower from side to side; and, at length, presents an oblong cleft, called *glottis*, the sides of which are the essential organ of voice.

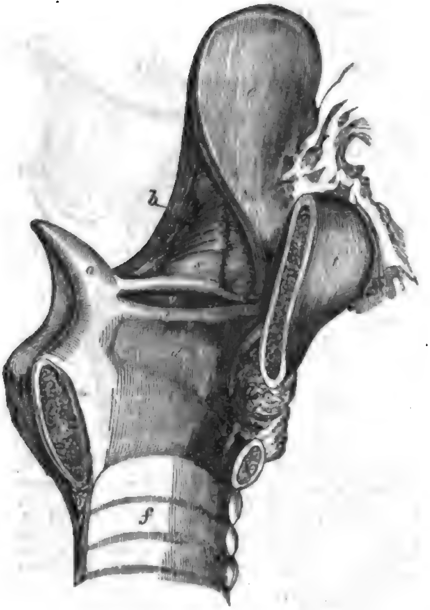
The larynx is composed of four cartilages—the *cricoid*, *thyroid*, and two *arytenoid.* The cricoid is the lowest of these, and is the inferior part of the organ;—that by which it joins the trachea. It is shaped like a ring, whence its name, but is much deeper behind than before. The thyroid is situate above the cricoid, with which it is articulated in a movable manner by means of its inferior cornua. In this way, the lower front margin of the thyroid, which is commonly separated by a short space from the upper margin of the cricoid, may be made to approach to or recede from it; as may be ascertained by placing the finger against the small depression felt externally, and observing its change of size when various tones are sounded. It will be observed, that the higher the tone the more the cartilages approximate, and that they separate in proportion to the depth of the tone. A ligament unites these cartilages—the *crico-thyroid*, which can be traced, although in a very thinned condition, over the whole of the periphery of the ventricle of the larynx, even as far as the pedicle of the epiglottis. This membrane is composed of the yellow elastic tissue—*tissu jaune*,—and, according to Dr. Leidy,[1] it presents, under the microscope, a good example of that substance, which enabled him to detect its presence in the ventricles of the larynx.

The thyroid is the large cartilage that occupies the anterior, prominent, and lateral part of the larynx. The arytenoid cartilages are two in number. They are much smaller than the others, and are articulated with the posterior part of the cricoid in a movable manner. Around this articulation is a synovial capsule. Before it is the *thyro-arytenoid* ligament; and, behind, a strong, ligamentous fascia, called, by M. Magendie,[2] from its attachments—*crico-arytenoid.* Three fibro-car-

[1] Amer. Journ. of the Medical Sciences, July, 1846, p. 142.
[2] Précis Elémentaire, i. 235.

tilages, likewise, enter into the constitution of the larynx. These are,—the *epiglottis;* and two small bodies, that tip the arytenoid cartilages, and are met with only in man—*capitula Santorini, supra-arytenoid cartilages* or *capitula cartilaginum arytenoïdarum.*

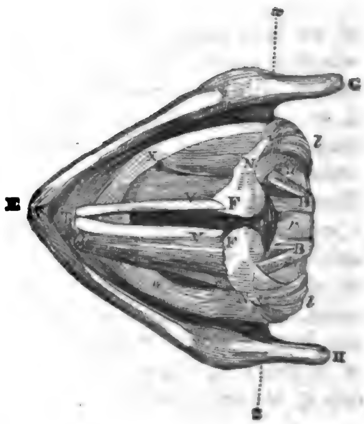
Fig. 195.



View of the interior of the left half of the Larynx, to show the Ventricle and Laryngeal Pouch. (After Hilton.)

a. Left arytenoid cartilage. *c, c.* Sections of the cricoid cartilage. *t.* Thyroid cartilage. *e.* Epiglottis. *v.* Left ventricle of the larynx. *r.* Left inferior or true vocal cord. *s.* Laryngeal pouch. *b.* Aryteno-epiglottidean muscle, or compressor sacculi laryngis. *f.* Inside of trachea, which has been added to this figure.

Fig. 196.



Larynx from above. (Willis.)

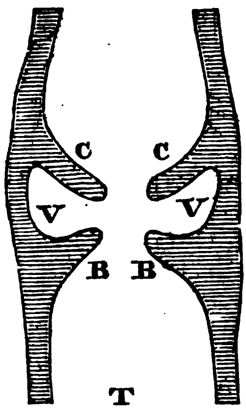
G E H. Thyroid cartilage, embracing the ring of the cricoid *r u x w*, and turning upon the axis *x x*. N F, N F. The arytenoid cartilages, connected by the arytenoideus transversus. T V, T V. The vocal ligaments. N X. The right crico-arytenoideus lateralis (the left being removed). V *k f*. The right thyro-arytenoideus (the left being removed). N *l*, N *l*. The crico-arytenoidei postici. B, B. The crico-arytenoid ligaments.

On examining the interior of the larynx, two clefts are seen—one above the other; the uppermost being usually oblong-shaped; ten or eleven lines long, and two or three broad; having the shape of a triangle, the apex forwards. It is circumscribed, anteriorly, by the thyroid cartilage and epiglottis; posteriorly, by the arytenoid cartilages; and, laterally, by two folds of mucous membrane, which pass from the epiglottis to each arytenoid cartilage, and are called *superior ligaments of the glottis* and *superior vocal cords.* A few lines below this is a second cleft, also oblong from before to behind and of a triangular shape, the base of which is behind. It is bounded anteriorly by the thyroid cartilage; posteriorly, by a muscle extending from one arytenoid cartilage to the other—the *arytenoideus;* and, laterally, by two folds, formed of the thyro-arytenoid ligament, passing from the anterior part of the arytenoid cartilage to the posterior part of the thy-

roid, and of a muscle of the same name. These folds are called *inferior ligaments* or *lips of the glottis* or *inferior vocal cords*. They are represented by T V, in Fig. 196, and B B, Fig. 197. Between these two clefts are the *sinuses* or *ventricles of the larynx*, V V, Fig. 197. The inferior, exterior, and superior sides of these are formed by the thyro-arytenoid muscles. By means of these ligaments—superior and inferior—the lips of the superior and inferior aperture are perfectly free, and unencumbered in their action.[1]

Anatomical descriptions will be found to give different significations to the word *glottis*. Some have applied it to the upper cleft; others to the lower; some to the ventricles of the larynx; and others to the whole space comprised between the inferior ligaments and top of the larynx. It is now, generally perhaps, restricted to the part of the larynx engaged in the production of voice, or usually considered to be so engaged,—that is, the space between the inferior ligaments plus the ligaments themselves;—and in this signification it will be employed here.

Fig. 197.



Scheme of the Larynx.

The mucous membrane, which lines the larynx, is continuous above with that of the mouth; below, with that of the trachea. It contains several mucous follicles, some of which are agglomerated near the superior ligaments of the glottis and the environs of the ventricles of the larynx, seeming to constitute distinct organs, which have been called *arytenoid glands*. A similar group exists between the epiglottis behind, and the os hyoides and thyroid cartilage before, which has been termed the *epiglottic gland*. The uses of this body are not clear. M. Magendie[2] conceives, that it favours the frequent slidings of the thyroid cartilage over the posterior surface of the os hyoides; keeps the epiglottis separated above from this bone; and, at the same time, furnishes it a very elastic support, which may aid it in the functions it has to execute, connected with voice and deglutition.

The larynx is capable of being moved as a whole, as well as in its component cartilages. It may be raised, depressed, or carried forwards or backwards. The movements, however, which are most concerned in the production of voice, are those effected by the action of the *intrinsic* muscles, as they have been termed. These are, 1st. The *crico-thyroid*, a thin, quadrilateral muscle, which arises from the anterior surface of the cricoid cartilage, and is inserted into the lower and inner border of the thyroid. M. Magendie[3] affirms, that its use is not, as generally imagined, to depress the thyroid on the cricoid, but to elevate the cricoid, approximate it to the thyroid, and even make it pass slightly under its inferior margin. The effects of its contraction must be to render the vocal

[1] Hilton, Guy's Hospital Reports, No. v. October, 1837, p. 519, and Leidy, American Journal of the Medical Sciences, p. 142, July, 1846.

[2] Précis, &c., i. 237.

[3] Ibid., i. 236.

ligaments tense. 2dly. The *crico-arytenoidei postici*, and *crico-arytenoidei laterales;* the former of which pass from the posterior surface of the cricoid to the outer angle of the base of the arytenoid; and the latter from the upper border of the side of the cricoid to the outer angle of the base of the arytenoid. The use of the crico-arytenoidei postici is to carry the arytenoid cartilages backwards, separating them at the same time from each other, and thus opening the glottis; the action of the crico-arytenoidei laterales is like that of the arytenoidei to bring together the inner edges of the arytenoid cartilages, and close the glottis. 3dly. The *arytenoid muscle*—of which there is only one. It extends across from one arytenoid cartilage to the other; and, by its contraction, brings them towards each other. 4thly. The *thyro-arytenoid muscle*, which, according to M. Magendie,[1] is the most important to be known of all the muscles of the larynx, as its vibrations produce the vocal sound. It forms the lips of the glottis, and Magendie describes it as constituting, also, "the inferior, superior, and lateral parietes of the ventricles of the larynx." Generally, it is considered to arise from the posterior surface of the thyroid cartilage, and the ligament connecting it with the cricoid, and to be inserted into the anterior edge of the base of the arytenoid. By drawing the point of the thyroid back, it must relax the vocal ligaments. Lastly.—The muscles of the epiglottis—the *thyro-epiglottideus, aryteno-epiglottideus superior, aryteno-epiglottideus inferior* (Hilton's muscle),[2] and some fibres that may be looked upon as *vestiges* of the *glotto-epiglotticus*, which exists in many animals. These muscles,—the position of which is indicated by the name,—modify by their contraction, the situation of the epiglottis.

Fig. 198.

Origin and Distribution of the Eighth Pair of Nerves.

The principal governors of the pitch of the voice, which is almost wholly regulated by the degree of tension of the vocal ligaments, are the crico-thyroid and thyro-arytenoid.

1, 3, 4. Medulla oblongata. 1. Corpus pyramidale of one side. 3. Corpus olivare. 4. Corpus restiforme. 2. Pons Varolii. 5. Facial nerve. 6. Origin of glosso-pharyngeal nerve. 7. Ganglion of Andersch. 8. Trunk of the nerve. 9. Spinal accessory nerve. 10. Ganglion of pneumogastric nerve. 11. Its plexiform ganglion. 12. Its trunk. 13. Its pharyngeal branch forming the pharyngeal plexus (14), assisted by a branch from the glosso-pharyngeal (8), and one from the superior laryngeal nerve (15). 16. Cardiac branches. 17. Recurrent laryngeal branch. 18. Anterior pulmonary branches. 19. Posterior pulmonary branches. 20. Œsophageal plexus. 21. Gastric branches. 22. Origin of spinal accessory nerve. 23. Its branches distributed to sterno-mastoid muscle. 24. Its branches to the trapezius muscle.

[1] Précis, &c., 236, and his Mémoire sur l'Epiglotte.

[2] Wilson's Anatomist's Vade Mecum, Amer. edit., p. 483, Philad., 1843.

The respective action of the different muscles has been given in a tabular form.[1]

Govern the Pitch of the Notes.

	Muscles	Action
Antagonists.	Crico-thyroidei Sterno-thyroidei	Depress the front of the thyroid cartilage on the cricoid and *stretch* the vocal ligaments; assisted by the arytenoideus and crico-arytenoidei postici.
	Thyro-arytenoidei Thyro-hyoidei	Elevate the front of the thyroid, and draw it towards the arytenoid, *relaxing* the vocal ligaments.

Govern the Aperture of the Glottis.

	Muscles	Action
Antagonists.	Crico-arytenoidei postici . . .	*Open* the Glottis.
	Crico-arytenoidei laterales . . . Arytenoideus	Press together the inner edges of the arytenoid cartilage, and *close* the glottis.

The intrinsic muscles of the larynx receive their nervous influence from the eighth pair (Fig. 198). Shortly after this nerve has issued from the cranium it gives off a branch, called *superior laryngeal*, which is distributed to the arytenoid and crico-thyroid muscles; and, after its entrance into the thorax, it furnishes a second, which ascends towards the larynx, and is, on that account, called *recurrent* or *inferior laryngeal*. It is distributed to the crico-arytenoidei postici, crico-arytenoidei laterales, and thyro-arytenoid muscles. No ramification of this nerve, according to M. Magendie, goes to the arytenoid, or crico-thyroid muscles. In these views, he is supported by M. J. Cloquet[2] and by many others. Other distinguished anatomists, however, maintain that the arytenoideus muscle receives a branch from each of the inferior laryngeals. Dr. Reid asserts, that he has repeatedly satisfied himself of the existence of this arytenoid branch of the inferior laryngeal, and the dissection is one, he says, which can leave no kind of doubt on the matter.[3]

In each animal species, the glottis has a construction corresponding to the kind of voice; and, when it is examined in the living animal—the dog for example—it enlarges and contracts alternately,—the arytenoid cartilages separating when the air enters the lungs, and approximating during expiration.

To the trachea the larynx is attached by a fibrous membrane, which unites the cricoid with the first ring of the trachea; and, above, it is connected with the os hyoides by a similar membrane—the *hyo-thyroid*, No. 2, Fig. 194,—as well as by the thyro-hyoid muscle.[4]

2. PHYSIOLOGY OF VOICE.

The production of voice requires, that air shall be sent from the lungs, which, in passing through the glottis, throws certain parts into vibration, and afterwards makes its exit by the *vocal tube*,—that is, by the mouth and nasal fossæ. Simple expiration does not, however, produce

[1] Carpenter's Human Physiology, 4th Amer. edit., § 604, Philad., 1850.

[2] Traité d'Anatomie Descriptive, ii. 622, Paris, 1816.

[3] Art. Par Vagum, by Dr. J. Reid, in Todd's Cyclopædia of Anat. and Physiol., Parts xxvii. and xxviii. p. 893, London, 1846-7. For an excellent description of the anatomy of the vocal apparatus, see J. Bishop, art Larynx, Cyclop. of Anat. and Physiol., Lond., Sept., 1840.

[4] Willis, in Cambridge Philosoph. Transact. for 1832, iv. 323.

it, otherwise we should have the vocal sound accompanying each contraction of the chest. Volition is necessary to excite the requisite action of the muscles of the larynx, as well as those of respiration; and by it the tone and intensity of voice are variously modified.

That voice is produced in the larynx, we have both direct and indirect testimony. An aperture made in the trachea, beneath the larynx, deprives both man and animals of it. This occurs also, if the aperture be made in the larynx beneath the inferior ligaments; but if above the glottis, so as to implicate the epiglottis and its muscles, the superior ligaments of the glottis, and even the upper portions of the arytenoid cartilages, voice continues. MM. Magendie[1] and J. Cloquet refer to the cases of two men, who had fistulæ in the trachea; and who were unable to speak unless the openings were accurately stopped by mechanical means. If, again, we take the trachea and larynx of an animal or man, and blow air forcibly into the tracheal extremity towards the larynx, no sound is produced, except what results from the friction of the air against the sides. But if we approximate the arytenoid cartilages, so that they touch at their inner surfaces, a sound is elicited, bearing some resemblance to the voice of the animal to which the larynx belongs;[2]—the sound being acute or grave according as the cartilages are pressed against each other with more or less force; and varying in intensity, according to the degree of force with which the air is sent through the tube. In this experiment, the inferior ligaments are seen to vibrate.

Paralysis of the intrinsic muscles of the larynx likewise produces dumbness; and this can be effected artificially. Much discussion at one time prevailed regarding the effect of tying or cutting the nerves distributed to these muscles. The experiments of Haighton[3] induced him to think, that the recurrent branches of the par vagum supply parts, which are essentially necessary to the formation of the voice; whilst the laryngeal seemed to him to affect only its modulation or tone. Subsequent experiments have sufficiently shown, that if both the recurrent nerves and the superior laryngeal are divided, complete aphonia results. M. Magendie[4] found, indeed, that when both recurrents,—which, he says, are distributed to the thyro-arytenoid muscles,—are cut, the voice is usually lost; whilst if one only be divided, the voice is but half destroyed. He noticed, however, that several animals, in which the recurrents had been cut, were still capable of eliciting acute sounds, when labouring under violent pain,—sounds, which were analogous to those that could be produced mechanically on the larynx of the dead animal, by blowing into the trachea and approximating the arytenoid cartilages; and this he attempts to explain by the distribution of the nerves to the larynx. The recurrents being divided, the thyro-arytenoid muscles are no longer capable of contracting, and aphonia results; but the arytenoid muscle, which receives its nerves from the superior laryngeal, still contracts; and, during a strong expiration, brings the ary-

[1] Precis, &c., i. 241, and his Journal de Physiologie, ix. 119.
[2] Biot, Traité Elémentaire de Physique, i. 462.
[3] Memoirs of the Medical Society of London, iii. 435.
[4] Précis, &c., i. 243.

tenoid cartilages together, so that the chink or cleft of the glottis is sufficiently narrow for the air to cause vibration in the thyro-arytenoid muscles, although they may not be in a state of contraction. From these, and other experiments, Bellingeri[1] infers, that the superior laryngeal nerve is the antagonist of the inferior laryngeal or recurrent,—the former producing constriction; the latter dilatation of the glottis. They, however, who affirm, that the distribution of the laryngeal nerves is not the same as that described by M. Magendie, assign different functions to the particular nerves. Thus, Mr. Hilton[2] infers from his observations—*first*, that the superior laryngeal is a nerve of sensation; because, independently of the crico-thyroideal nerve, it is distributed exclusively to the mucous membrane, areolar tissue, and glands; and *secondly*, that the inferior or recurrent must be the proper motive nerve to the larynx, as it alone supplies all the muscles, which act immediately upon the column of air passing to and from the lungs. Dr. Reid[3] too, concludes from his various experiments;—*first*, that the superior laryngeal furnishes one muscle only with motor filaments,—the crico-thyroid. *Secondly*, that the superior laryngeal furnishes all, or nearly all, the sensitive filaments of the larynx, and some of those distributed upon the mucous surface of the pharynx. *Thirdly*, that the inferior laryngeal or recurrent furnishes the sensitive filaments to the upper part of the trachea, a few to the mucous surface of the pharynx, and still fewer to the mucous surface of the larynx; and *fourthly*, that when any irritant is applied to the mucous membrane of the larynx in a healthy state, this does not excite the contraction of the muscles, which move the arytenoid cartilages, by acting directly upon them through the mucous membrane, but the contraction takes place by a reflex action, in the performance of which the superior laryngeal is the sensitive, and the inferior laryngeal the motor nerve.

It is obvious from this discrepancy amongst observers, that we have yet much to learn before we can pronounce with certainty on the precise function of those nerves.

Every part of the larynx, with the exception of the inferior ligaments, may be destroyed, and the voice continue. Bichat split the upper edge of the superior ligaments of the glottis, without its being destroyed; and the excision of the tops of the arytenoid cartilages had no more effect. Magendie divided with impunity the epiglottis and its muscles: voice was accomplished, until he cut the middle of the arytenoid cartilages or split the thyroid cartilages longitudinally, when he, of course, destroyed the glottis. Lastly, when the larynx is exposed in a living animal, so that the different parts can be seen at the time when voice is accomplished,—the superior ligaments, according to Bichat and Magendie, who have performed the experiment, are manifestly unconcerned in the function, whilst the inferior vibrate distinctly. These

[1] Ragionamenti, Sperienze, &c., comprovanti l'Antagonismo Nervoso, &c., Torino, 1833; noticed in Edinb. Méd. and Surg. Journal, p. 172, Jan., 1835.

[2] Op. cit., p. 518, and Mr. Cock, on the Crico-Thyroideal Nerve, a branch of the superior laryngeal, ibid., p. 313.

[3] Op. cit., p. 145.

These muscles, too, are only the proper muscles of the larynx, or those restricted in their attachments to its five cartilages. They are but a few of the muscles of voice. In speaking, we use a great many more. Fifteen pairs of different muscles, attached to the cartilages or os hyoides, and acting as agents, antagonists, or directors, are constantly employed in keeping the cartilages steady, regulating their situation, and moving them as occasion requires,—upwards and downwards, backwards and forwards, and in every intermediate direction, according to the course of the fibres, or in the diagonal between different fibres. These muscles, independently of the former, are susceptible, it is calculated, of upwards of 1,073,841,800 different combinations; and, when they co-operate with the seven pairs of the larynx, of 17592186,044,415; exclusive of the changes that must arise from the different degrees of force, velocity, &c., with which they may be brought into action. But these muscles are not the whole that co-operate with the larynx in the production of voice. The diaphragm, abdominal muscles, intercostals, and all, that directly or indirectly act on the air, or on the parts to which the muscles of the glottis or os hyoides are attached, contribute their share. The numerical estimate would, consequently, require to be largely augmented. Mr. Bishop computes the number of muscles brought into action at the same time in the ordinary modulations of the voice to be one hundred.[1] Such calculations are, of course, only approximate; but they show the inconceivable variety of movement of which the vocal apparatus is directly or indirectly susceptible.

The tone of the voice has been a great stumbling-block to the physiologist and physicist. The mode, in which it is produced, and the parts more immediately concerned in the function, have been the object of various theories or hypotheses, regarding the voice.

Galen, under his theory, that the larynx is a wind instrument of the flute kind, of which the glottis is the beak and the trachea the body of the flute, ascribed the variety of tones to two causes—to variation in the length of the musical instrument, and in the embouchure. In the theory of Dodart, in which the human vocal instrument was likened to a horn, the inferior ligaments of the glottis being compared to the lips of the performer, no importance was attached to variation in the length of the instrument. He attributed variety of tones to simple alteration in the *embouchure* or mouth-piece,—in other words, to changes in the size of the glottis, by the action of its appropriate muscles; and the rising and falling of the larynx, he regarded as serving no other purpose than that of influencing mechanically the size of the aperture of the glottis; whilst Ferrein, who regarded the larynx as a stringed instrument, accounted for the variety of tones by different degrees of tension and length of the inferior ligaments of the glottis or *vocal cords*. In the production of acute tones, these cords were stretched and shortened. For grave tones, they were relaxed, and lengthened. He was of opinion, that the length of the vocal tube had no influence on the tone.

[1] The London and Edinburgh Philosoph. Magazine, &c., for Sept., 1836, p. 209.

In later years, several new views have been propounded on this subject, and chiefly by MM. Cuvier, Dutrochet, Magendie, Biot, Savart, &c.,—men of the highest eminence in various departments of physical science.

M. Cuvier[1] attributes variety of tones, in the first place, to varied length of the vocal tube, and to differences in size of the aperture of the glottis; and, secondly, to the shape and condition of the external aperture of the tube,—that is, of the lips and nose. The larynx he regards as a wind instrument, in which the inferior ligaments act, not as cords, but like the reed of a clarionet, or the *lame* of an organ pipe. The lungs and their external muscular apparatus constitute the reservoir of air and bellows; the trachea conducts the air, and the glottis is the embouchure with its reed; the mouth, and the whole of the space comprised between the glottis and the opening of the lips, being the body of the instrument; whilst the openings of the nostrils are lateral holes, that permit the size of the instrument to be varied. The tones are changed by three causes of a similar character to those that modify them in musical instruments;—the length of the body of the instrument, and the variableness of the embouchure, and of the aperture at the lower extremity of the instrument. The condition of the external aperture of the vocal tube has, doubtless, much to do with the character of the tone produced by the glottis; but its influence appears to be greatly limited to giving it rotundity, volume, or the contrary,—as will be seen hereafter; although analogy would seem to show, that the tone may be varied by more or less closure of the aperture. Many different notes can be produced in the first joint of a flute, if we modify the size of the opening at its extremity by passing the thumb more or less within it. It is doubtful, however, whether in man the altered size of the external aperture, or the elongation or decurtation of the tube exerts as much influence in the production of acute or grave sounds as Cuvier imagined.

M. Dutrochet[2] again, believes, that the vocal tube has no influence in the production of tones, and that the larynx is a simple vibrating instrument, uncomplicated with a tube, the vocal sound being caused by the vibrations into which the vocal cords are thrown by the impulse of the expired air. In his experiments, he saw the inferior ligaments vibrate; and he concludes, that the tone of the voice depends upon the number of vibrations of those ligaments in a given time, and that their number will necessarily vary greatly, as the dimensions of the ligaments,—that is, their length and thickness,—and their elasticity, are susceptible of incessant changes, by the contraction of the thyro-arytenoid muscle, of which they are essentially composed,—the ligament, covering the muscle, serving only "to prevent the collisions of the muscles at the time of vibration,"—as well as by that of the other intrinsic muscles of the larynx.

MM. Biot and Magendie[3] dissent from M. Dutrochet in some important

[1] Leçons d'Anatomie Comparée, tom. iv. 445.

[2] Mém. pour servir à l'Histoire Anat. et Physiol. des Végétaux et des Animaux, t. ii., Paris, 1837; and Adelon, Physiologie de l'Homme, édit. cit., ii. 239.

[3] Précis Élémentaire, &c., i. 248.

points. Like him, they do not consider the human larynx to constitute a stringed instrument. They regard it as a variety of reed instrument, but consider the vocal tube to be of moment in the production of the voice. The objections they urge against the view of its resembling a stringed instrument, are,—the kind of articulation between the arytenoid and cricoid cartilages, which admits of motion inwards and outwards only; and they ask how the vocal cords can retain the length requisite for the production of grave tones; and how they can elicit sounds of a volume so considerable as those of the human voice? They esteem it, consequently, a reed instrument of such nature as to be capable of affording very grave tones with a pipe of little length; and, with slight variation of its length, susceptible, not only of furnishing a certain series of sounds in harmonic progression, but all the imaginable sounds and shades of sounds, in the compass of the musical scale which each voice embraces.

The theory of the reed instrument they apply to the vocal apparatus. The lips of the glottis are the reed, and the thyro-arytenoid muscles render them fit for vibrating. In his experiments, made on living dogs, M. Magendie saw, that when grave sounds were produced, the ligaments of the glottis vibrated in their whole extent, and the expired air issued through the whole of the glottis. In acute sounds, on the other hand, they vibrated only at their posterior part, and the air passed out through the part only that vibrated, the aperture being, consequently, diminished; and, when the sounds became very acute, they vibrated only at their arytenoid extremity, and scarcely any air issued; so that tones beyond a certain degree of acuteness, cannot be produced in consequence of the complete closure of the glottis. The arytenoid muscle, whose chief use is to close the glottis at its posterior extremity, he conceives to be the principal agent in the production of acute sounds, and this idea was confirmed by the section of the two laryngeal nerves that give motion to this muscle, which was followed by loss of the power of producing almost all the acute tones; the voice, at the same time, acquiring a degree of habitual graveness, which it did not previously possess. The influence of contraction of the thyro-arytenoid muscles on the tones is exerted in increasing or diminishing the elasticity of the ligaments, and thus, in modifying the rapidity of the vibrations, so as to favor the production of acute or grave tones. He thinks, too, that the contraction of these muscles concurs greatly in closing, in part, the glottis, particularly its anterior half; although the course of its fibres, it would appear, ought rather to widen the aperture. The trachea or *porte-vent* has usually been thought to exert no influence on the nature of the sound produced. It has been conceived, however, by M. Grenié and others, that its elongation or decurtation may occasion some modification.

Thus much for the part that resembles the reed—MM. Biot and Magendie include in their theory of the voice the action of the vocal tube likewise. This tube being, in man, capable of elongation and decurtation, of dilatation and contraction, and of assuming an infinite number of shapes, they think it well adapted, if placed in harmonic relation with the larynx, for fulfilling the functions of the body of a reed instru-

ment,—and thus of favouring the production of the numerous tones of which the voice is capable; of augmenting the intensity of the vocal sound by assuming a conical shape with a wide external aperture; of giving rotundity and sweetness by the proper arrangement of its external outlet, or of entirely arresting it by the closure of the outlet. The larynx rises in the production of acute, and sinks in that of grave sounds. The vocal tube is, consequently, shortened in the former case; elongated in the latter. It experiences, also, a simultaneous change in its width. When the larynx descends,—in other words, when the vocal tube is elongated, the thyroid cartilage is depressed, and separated from the os hyoides by the whole height of the thyro-hyoid membrane. By this separation, the epiglottic gland is carried forwards, and lodged in the concavity at the posterior surface of the os hyoides. The gland drags after it the epiglottis; and a considerable enlargement in width occurs at the inferior part of the vocal tube. The opposite effect results when the larynx rises. The use of the ventricles of the larynx, M. Magendie[1] considers to be, to isolate the inferior ligaments, so that they may vibrate freely in the air. Lastly; in this theory the epiglottis has a use assigned to it which is novel. In certain experiments, instituted by M. Grenié[2] for the improvement of reed instruments—being desirous of increasing the intensity of sound without changing the reed in any respect—he found that, to succeed, he was compelled to augment gradually the strength of the current of air; but this augmentation, by rendering the sounds stronger caused them to rise. To remedy this inconvenience, M. Grenié found nothing answer except placing obliquely in the tube immediately below the reed a supple, elastic tongue, nearly as the epiglottis is placed above the glottis. From this, M. Magendie[3] infers, that the epiglottis may assist in giving to man the faculty of increasing or inflating the vocal sound, without causing it to mount; but, as Mr. Bishop[4] properly remarks, neither the elevation nor depression of the epiglottis can affect, or regulate the vibrations of the glottis.

Such are the main propositions of the theory of the voice by MM. Biot and Magendie. The larynx represents a reed with a double tongue; the tones of which are acute in proportion to the decurtation of the laminæ; and grave in proportion to their length. They admit, however, that, although the analogy between the organ of voice and the reed is just, the identity is not complete. The ordinary reeds are composed of rectangular laminæ; fixed at one side, but loose on the three others; whilst, in the larynx, the vibrating laminæ, which are also nearly rectangular, are fixed by three sides, and free by one only. Moreover, the tones of the ordinary reed can be made to rise or descend by varying its length; whilst in the laminæ of the larynx the width varies. Lastly—say they—in musical instruments, reeds are never employed, whose movable laminæ can vary in thickness and elasticity every moment, as is the case with the ligaments of the glottis; so that,

[1] Précis, &c., i. 252; see, also, Sir C. Bell, Philos. Transact. for 1832; and Nervous System, 3d edit., p. 484, Lond., 1837.
[2] Biot, Précis Elémentaire de Physique, p. 399.
[3] Précis, &c., i. 252.
[4] London and Edinburgh Philosophical Magazine, p. 205, for Sept. 1836.

although we may conceive, that the larynx can produce voice and vary its tones, in the manner of a reed instrument, we are unable to demonstrate the particulars of its mode of action.

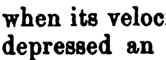
All the more modern theories—detailed above, at more or less length—agree, then, in considering the larynx to be a wind instrument of the reed kind: they differ, chiefly, in the *rôle* which they assign to the vocal tube in causing the variation of tones.

M. Savart[1] has propounded a theory of voice, in which he differs from MM. Cuvier, Dutrochet, and Magendie. He denies, that the mechanism of the voice resembles that of the reed instrument, and returns to the old idea, which referred the vocal organ to an instrument of the flute kind. The sounds of the human voice have,—he remarks,—a peculiar character, which no musical instrument can imitate; and this must necessarily be the case, as they are produced by a mechanism founded on principles which do not serve as a basis in the construction of any of our instruments. He conceives that the production of the voice is analogous to that of the sound in the tube of a flute; and that the small column of air, contained in the larynx and mouth, by the nature of the elastic parietes which bound them, as well as by the mode in which it is thrown into vibrations, is susceptible of rendering sounds of a particular nature, and, at the same time, much more grave than the dimensions would seem to permit.

In the tube of a flute, the column of air within is the sonorous body. A sound is first produced at the *embouchure* of the instrument, by the division which the air experiences when blown in; and this excites similar sonorous undulations in the column of air that fills the tube. The sound, resulting in this way, is grave in proportion to the length of the tube; and in order to vary its tones, the instrument has apertures in its sides, by means of which its length may be modified.

In assimilating the human vocal apparatus to a flute, the great difficulty has been to explain how, with so short a tube as the vocal tube in man, and one so little variable in length, tones so different, and especially so grave, can be produced. To account for this, M. Savart establishes a number of physical facts, previously unknown or unnoticed. In organ-pipes of great length, the velocity of the current of air, which acts as a motor, has but little influence on the number of oscillations. When the length of the pipe, for instance, is twelve or fifteen times greater than its diameter, it is difficult to vary the sound a semitone. When air is forcibly driven in, it rises an octave; and, when its velocity is diminished, the sound becomes more feeble; but is depressed an almost imperceptible quantity. In short pipes, on the contrary, the influence of the velocity of the current of air is much greater, and several tones can be elicited. The bird-call used by sportsmen is illustrative of this principle. It is a small instrument, employed for imitating the notes of certain birds, and consists of a cylindrical tube, about three-fourths of an inch in diameter, and a third of an inch high; closed at each end by a thin, flat plate,

Fig. 199.

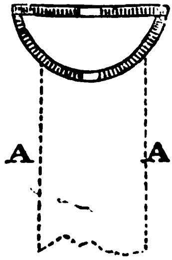


Scheme of a Bird-call.

[1] Journal de Physiologie, v. 367, Paris, 1825; and Annales de Physique et de Chimie, xxx. 64, and xxxii.

which is pierced, at its centre, by a hole about the sixth of an inch in diameter. Sometimes, it has the shape represented in the next marginal figure. By placing this instrument between the teeth and lips, and forcing air, with more or less strength, through the two apertures, different sounds can be produced. This is more certainly effected, by attaching a *porte-vent* to the whistle, as A A, Fig. 200, when it is capable of producing all the sounds comprised in an extent of from an octave and a half to two octaves. M. Savart found, that, other things being equal, the diameter of the apertures has an appreciable influence on the acuteness or graveness of the sounds, which are graver the larger the orifices. The nature of the parietes of the instrument appeared, also, to exert some effect on the number of oscillations, and the quality of the sounds; and if, in the hemispherical whistle, Fig. 200, the plain plate was replaced by a thin leaf of some extensible substance, as parchment, the sounds issued more rapidly, and were usually more grave, full, and agreeable, than when it was formed of a more solid substance.

Fig. 200.



Scheme of a Bird-call.

It is an opinion generally admitted, that the material, which composes an organ-pipe, has no influence on the number of vibrations, which the column of air, contained in it, is capable of executing. This is true as regards long pipes; but, according to M. Savart, it is not so with short; and the nature of the *biseau*[1] he conceives, may have a great influence, even on the sound of long pipes. For instance, if we substitute, for the stiff lamina, which forms the *biseau* of an organ pipe two feet long and two inches on the side, a lamina, formed of some elastic substance, as skin or parchment, so arranged as to admit of being stretched at pleasure—by gradually increasing the tension of the membrane, at the same time that we increase the velocity of the current of air, the tone may be made to vary a fourth, and even a fifth. In shorter tubes, the much greater influence of the velocity of the current of air being united to that of the tension of the *biseau*, the result is still more evident. Thus, the sound of a cubical tube may be easily lowered an octave, when the parietes of the *biseau* are susceptible of different degrees of tension; but when all the parietes of a short pipe are of a nature to enter into vibration along with the air they contain, and when their degree of tension can be, moreover, varied, they have such an influence on the number of vibrations, that the sound may be greatly modified. Short tubes, open at both extremities, and formed of elastic parietes, are also susceptible of producing a great variety of sounds, even when they are only partly membranous; and the quality of the sound of membranous tubes is said to be somewhat peculiar,—partaking of that of the flute, and of the free reed. Again, in order that a mass of air shall enter into vibration, a sound must be produced in some part of it. In an organ pipe, for example, a sound

[1] The *biseau* or *languette* is the diaphragm placed between the body of an organ pipe and its foot.

is first excited at the embouchure, which throws the column of air, within the instrument, into vibration. Every sound, indeed, produced at the orifice of a column of air, throws it into vibration, provided its dimensions be adapted to the length of the waves produced directly:—hence the utility of a musical pipe having parietes susceptible of varying in size and tension, whatever may be the character of its *embouchure*. Lastly.—The fundamental note of a tube closed at one end, whose diameter is every where the same, is an octave lower than the sound of the same tube, when open at both extremities. But this is not the case with tubes that are of unequal diameter, conical and pyramidal, &c., when made to vibrate at their narrowest part. The tone produced in such case increases in graveness, according to the difference between its narrow and expanded portions.

These different physical conditions M. Savart invokes to account for the different tones of the human voice,—under the theory, that the vocal organ—composed of the larynx, pharynx, and mouth—forms a conical tube, in which the air is set in vibration by a movement similar to that which prevails in organ pipes. The trachea is terminated above by a cleft—the glottis—which is the inferior aperture of the vocal instrument. This cleft, which is capable of being rendered more or less narrow, plays the same part as the *lumière des tuyaux à bouche* or narrow space in the organ pipe, at the edge of the *biseau* or *languette*, along which the air passes. The air clears it, traverses the ventricles of the larynx or cavity of the instrument, and strikes the superior ligaments. These surround the upper aperture of the instrument, and fulfil the same function as the *biseau* of the organ pipe. The air, contained in the interior of the larynx, now vibrates, and sound is produced. This sound acquires intensity, from the waves that constitute it extending into the vocal tube above the larynx, and exciting in the column of air filling it, a movement similar to that occasioned in the tube of a flute; except, that the tone is susceptible of much variation, because the larynx, being a short tube, can give rise to various tones by simple modification in the velocity of the air sent through it: moreover, the vocal tube has the same power, its parietes being membranous, of a vibratory nature, and capable of different degrees of tension. The inferior or outer part of the vocal tube is equally constituted of elastic parietes, susceptible of varied tension; and the mouth, by modifying the dimensions of the column of air within the tube, exerts an influence on the number of vibrations, which the column is capable of experiencing; whilst the lips can convert the channel at pleasure into an open or closed conical tube. Certain sounds, M. Savart affirms, are produced altogether in the ventricles of the larynx, as those of pain, and the *falsetto* voice, for example. They can be elicited when the vocal tube has been removed; and there are animals, in which the vocal organ is reduced to the ventricles of the larynx,—frogs for example. Savart, consequently, considers, that the human vocal organ bears in its essential parts, C C, B B, Fig. 197, a striking analogy to the action of the bird-call; and, in this way, he explains the use of the superior ligaments C C, which are entirely overlooked in the different theories of the voice previously propounded.

We have given M. Savart's view at some length, in consequence of its ingenuity, and of its seeming to explain as well as any other theory the varied tones of which the human voice is susceptible. It cannot, however, be esteemed established, inasmuch as it is diametrically opposed, in many of its points, to the observations and vivisections of distinguished physiologists; who, it has been seen, affirm, that voice is produced solely by the inferior ligaments; that all the parts above these may be destroyed, and yet voice continue; and that a wound in the ventricles, which permits the exit of air through the parietes of the larynx, does not destroy the function. Our notions on this point must not, therefore, be considered definite. Farther experiments are necessary; and, in all deductions from them, great importance will have to be attached to the vital action of the organs, especially of the intrinsic muscles, which are capable of modifying the situation of parts, and the character of the function in myriads of inappreciable ways. It may be added, that, more recently, Mr. J. Bishop,[1] from his numerous investigations, has arrived at the conclusion, that the human voice results from the vibration of membranous ligaments, in obedience, *first*, to the laws of musical strings; *secondly*, to those of reed instruments; and *thirdly* to those of membranous pipes; and that the vocal organs combine in reality the actions of each of these instruments, and exhibit in conjunction the perfect type of every one of them.

3. *Timbre or Quality of Voice.*

In the preliminary essay on sound, attached to the physiology of audition, it was remarked, that the cause of the different timbres of sound, in the various musical instruments, has hitherto remained unexplained. The same remark is applicable to the timbre of the voice. Each individual has his own, by which he is distinguished from those around him; and it is the same with each sex and period of life. In this the larynx is, doubtless, concerned; but in what manner is not clear. The feminine timbre or stamp, that characterizes the voice of the child and the eunuch, would appear to be generally connected with the cartilaginous condition of the larynx; whilst the masculine voice, which is sometimes met with in the female, is connected with the osseous condition of the parts, and especially of the thyroid cartilage. An infinity of modifications may also be produced by changes in the thickness, elasticity, and size of the lips of the glottis. The vocal tube probably exerts great influence in this respect by its shape, as well as by the nature of the material composing it. Such conditions, at least, appear to modify the timbre of our wind instruments. The timbre of a flute, made of glass or brass, is very different from that of one formed of wood, although the instruments may resemble each other in every other respect. The form of the body of the instrument has, also, considerable effect. If it be conical, and wider towards its outlet, as in the clarionet, or hautboy, the quality of the sound is shrill. If it be entirely cylindrical, as in the flute, we have the soft quality, which cha-

[1] Proceedings of the Royal Society, No. 65, Lond., 1847.

racterizes that instrument; and on the other hand, if the tube be expanded at its middle portion, the quality of the sound is raucous and dull. It is probable, therefore, that we must reckon, amongst the elements of the varying character of the timbre or stamp of the voice, the different conditions of the vocal tube, as to length, width, and form; and that we must likewise include the position and shape of the tongue, of the velum palati, mouth and nose, the presence or want of teeth, &c., all which modify the voice considerably. The first modification takes place, probably, in the ventricles of the larynx, in which the voice acquires more rotundity and expansion. It was remarked by Dr. Isaac Parrish,[1] that a peculiar change was induced in two cases by the excision of the tonsils. The voice was rendered shrill and whistling.

By the generality of physiologists, it is conceived, that the voice enters the different nasal fossæ, and, by resounding in them, a timbre or character is given to it, which it would not otherwise possess. According to this view, when it is prevented from passing through the nose, from any cause, it acquires the *nasal* twang; or, by a singular inaccuracy of language, we are said "to talk through the nose." M. Magendie,[2] however, considers, that whenever the voice passes through the nasal fossæ, it becomes disagreeable and nasal. The simple experiment of holding the nose exhibits, that, in the enunciation of the true vocal sounds, unmodified by the action of the organs of articulation, the timbre or quality is materially altered; and we shall see, hereafter, that there are certain letters, that do not admit of enunciation, unless the nasal fossæ be pervious—the *m*, the *n*, and *ng*, for example. It would seem that, under ordinary circumstances, the sound, after it is produced in the larynx, flows out by both channels; and that, if we either shut off the passage through the nose altogether, or attempt to pass it more than usually through the nasal fossæ, the voice becomes *nasal*. The fine, sharp voice prior to puberty is especially owing to the narrowness of the glottis, the shortness of the ligaments, and, according to M. Malgaigne,[3] the want of developement of the nasal cavities. At puberty, the size of the opening of the larynx is doubled; the ligaments enlarge, and the size of the passages of the nose is augmented. The timbre now becomes raucous, dull, and coarse; and for a time the harmony of the voice is lost. M. Bennati,[4] himself an excellent theoretical and practical musician, whose voice marks three octaves, advises, that the voice should not be much exerted during this revolution. He has known perseverance in singing at this time in several instances completely destroy the voice.

Not only does the voice, when produced in the larynx, pass out by the vocal tube, but it resounds along the tracheal and bronchial tubes, giving rise to the resonance or thrill, audible in certain parts of the chest, more especially, when the ear or the stethoscope is placed over them; and, when cavities exist in the lungs, in the consumptive, if the

[1] Quarterly Summary of the Transactions of the College of Physicians of Philadelphia, Nov. and Dec., 1841, and Jan., 1842.

[2] Précis Elémentaire, i. 254.

[3] Archives Générales de Médecine, pp. 201 and 214, Février, 1831.

[4] Recherches sur le Mécanisme de la Voix Humaine, Paris, 1832.

ear be placed upon the chest, immediately over one of them, the voice will appear to come directly up to the ear. The same thing happens, if the stethoscope be used. In this case, when the extremity of the instrument is applied over the vomica, the voice appears to pass directly through the tube to the ear, so as to give rise to what has been termed *pectoriloquy*. M. Adelon[1] conceives, that this distribution of the sound along the trachea or *porte-vent* and the lungs may suggest that the condition of these organs has some effect on the quality of the voice.

In speaking of the timbre of the voice in different individuals, we have had in view the natural quality,—not that which is the result of imitative action, and which cán be maintained for a time only. Many of the conditions, which have been described as regulating the timbre, are voluntary, especially that of the shape of the vocal tube. In this way we can modify the timbre and imitate voices different from our own. The *table d'hôte* of many of the hotels of continental Europe is enlivened by the presence of individuals, capable of not only imitating various kinds of birds, but the timbres of different musical instruments; and the success which attended the personation of the voices of public speakers, by Matthews, Yates, and others, is sufficient evidence of the fidelity of their representations. We see the difference between the natural and imitative voice strongly exemplified in one of the feathered songsters of our forests, *turdus polyglottis* or *mocking-bird*, which is capable of imitating, not only the voices of different birds, but sounds of other character, which cannot be regarded in the light of accomplishments.

There is a singular variety of the imitative voice, now employed only for purposes of amusement—but, of old, perhaps, used in the Pagan temples, by the priests, to infuse confidence in the oracular dicta of the gods—which requires notice: this is *engastrimism* or *ventriloquism*. Both these terms, by their derivation, indicate the views at one time entertained of its physiology, namely, that the voice of the ventriloquist is made to resound in the abdomen, in some inexplicable manner, so as to give rise to the peculiarity it exhibits. This singular view seems to have been once embraced by M. Richerand.[2] "At first," says he, "I had conjectured, that a great part of the air expelled by expiration did not pass out by the mouth and nostrils, but was swallowed and carried into the stomach; and, being reflected in some part of the digestive canal, gave rise to a real echo; but, having afterwards more attentively observed this curious phenomenon on Mr. Fitzjames, who exhibits it in its greatest perfection, I was soon convinced that the name of ventriloquism is by no means applicable." M. Richerand was probably the last remnant of the supporters of the ancient vague hypothesis; and his views soon underwent conversion.

Another, equally unfounded notion, at one time entertained, was, that the ventriloquist possesses a double or triple larynx. It is now admitted, that the voice is produced at the ordinary place, and is modi-

[1] Physiologie de l'Homme, edit. cit., ii. 204.

[2] Elémens de Physiologie, édit. 13ème, par M. Bérard ainé, édit. Belge, cxciv. p. 300, Bruxelles, 1837.

fied in intensity and quality by actions of the larynx and vocal tube, so as to give rise to the deceptions we experience. It is known, that our appreciation of the distance and nature of a sonorous body is formed from the intensity and quality of the sound proceeding from it. We instinctively believe, that a loud sound proceeds from a near object, and a feeble sound from one more remote; accordingly, if the intensity and quality of the sound from a known body be such as to impress us with the idea that it is more remote than it really is, we incur an acoustic illusion. The ventriloquist takes advantage of this source of illusion; and, by skilfully regulating the force and timbre of his voice, leads us irresistibly into error. Mr. Dugald Stewart[1] gives some examples of this kind of illusion. He mentions having seen a person, who, by counterfeiting the actions of a performer on the violin, whilst he imitated the music by his voice, riveted the eyes of the audience on the instrument, although every sound they heard proceeded from his own mouth. Mr. Savile Carey, who imitated the whistling of the wind through a narrow chink, told Mr. Stewart, that he had frequently practised the deception in the corner of a coffee-house, and that he seldom failed to see some of the company rise to examine the tightness of the windows; whilst others, more intent on the newspapers, contented themselves with putting on their hats, and buttoning their coats.[2] It is to account for the mode in which this is effected, that different hypotheses have been from time to time entertained. Haller, Nollet, Mayer,[3] and others, believed, that the voice is formed during inspiration; but this does not seem to be the case. Voice can certainly be effected during inspiration; but it is raucous, unequal, and of trifling extent only. MM. Dumas and Lauth[4] considered ventriloquism to be a kind of rumination of sounds; the voice, formed in the larynx, being sent into the interior of the chest, attaining there a peculiar timbre, and issuing of a dull character. M. Richerand is of opinion, that the whole mechanism consists in a slow, gradual expiration, which is always preceded by a deep inspiration. By means of this, the ventriloquist introduces into his lungs a considerable quantity of air, the exit of which he carefully regulates; and a similar view is embraced by Prof. J. Müller,[5] who asserts that the sounds uttered by the ventriloquist can be perfectly elicited by a method, which, he is convinced, must be adopted by ventriloquists. This method consists in inspiring deeply so as to protrude the abdominal viscera by the descent of the diaphragm, and then speaking, whilst expiration is performed very slowly through a narrow glottis by means of the lateral parietes of the thorax alone, the diaphragm maintaining its depressed position; and M. Colombat confirms the general accuracy of Professor Müller's view, remarking that by continually practising in a manner somewhat similar to that pointed out by him he was enabled to attain considerable skill in the production of

[1] Elements of the Philosophy of the Human Mind, 3d edit., Lond., 1808; Amer. edit., Brattleborough (Vermont), 1813.

[2] Brewster, Natural Magic, Amer. edit., p. 158, New York, 1832.

[3] Lepelletier, Physiologie Médicale, &c., iv. 213, Paris, 1833.

[4] Mémoir. de la Société des Sciences Agricol. de Strasbourg, i. 427.

[5] Elements of Physiology, by Baly, p. 1054, Lond., 1838.

this variety of voice.[1] Mr. Gough[2] attempts to explain the phenomenon upon the principle of echoes:—the ventriloquist, he conceives, selects a room, well disposed for echoes in various parts of it, and produces false voices, by directing his natural voice in a straight line towards such echoing parts, instead of in a straight line towards the audience, who are supposed, by Mr. Gough, to be placed designedly by the ventriloquist on one or both sides of him. A sufficient answer to this is, that the practised ventriloquist is careless about the room chosen for his exhibitions; and habitually performs where this system of echoes would be totally impracticable.

But it is well to inquire what the ventriloquists themselves say of the mechanism of their art. We pass over the explanation of Baron von Mengen, an Austrian colonel, who forms a kind of vocal organ between his tongue and his left cheek, if we understand his description correctly, and keeps a reservoir of air in his throat to throw the organ into vibration. His object must evidently have been to mislead.

In 1811, M. L'Espagnol, a young physician, maintained a thesis on this subject before the *Faculté de Médecine* of Paris, which may be regarded as at least an honest exposition of his belief regarding the mode in which the phenomenon was effected in his own person. According to him, the whole is dependent upon the action of the velum pendulum palati. In ordinary voice, he remarks, a part of the sound passes directly through the mouth, whilst another part resounds in the nasal fossæ. If we are near the person who is speaking, these two sounds strike equally and almost synchronously upon the ear; but if at a distance, we hear only the first of the two sounds; when the voice appears more feeble, and, especially, has another timbre, which experience makes us judge to be that of the voice at a distance. The difference, says M. L'Espagnol, between the voice that proceeds from a near, and that from a more distant object is, that in the former we hear the mixture of the two sounds; whilst in the latter we hear that sound only, which issues directly from the mouth. Now, the secret of the ventriloquist is, to permit this direct sound only to pass to the ear, and prevent the nasal sound from being produced, or at least from being heard; and this is done by the elevation of the velum pendulum palati: the vocal sound does not then resound in the nasal fossæ; the direct sound is alone produced; the voice has the feebleness and timbre that belong to the distant voice, and is judged to proceed from a distance; and if, during the performance, it seems to come from any determinate place, it is owing to the ventriloquist attracting attention to it: the voice itself need only appear to proceed from a distance; and this it does more or less, according as the pendulous veil has more or less completely prevented the sound from issuing by the nasal fossæ. The ventriloquist thus, according to M. L'Espagnol, makes the voice appear nearer or more remote at pleasure, by raising or depressing the velum palati. He denies, that he speaks with his mouth closed; and affirms, that he articulates, but to a trifling extent only.

[1] Baly and Kirkes, Recent Advances in the Physiology of Motion, the Senses, Generation, and Developement, p. 11, Lond., 1848.
[2] Manchester Memoirs, 2d edit., v. 622, Lond., 1789.

M. Comte, another ventriloquist, and of some celebrity, who has endeavoured to explain the physiology of his art, affirms, that voice takes place as usual in the larynx; but is modified by the action of other parts of the apparatus; that inspiration directs it into the thorax, where it resounds; and that both strength and flexibility are required in the organ to produce this effect. This, however, is no explanation. It is now universally admitted, that the voice of the ventriloquist is produced in the larynx; and that its character and intensity are modified by the action of other parts of the apparatus, but the particular agency that produces it is not elucidated by any of these attempted explanations of the ventriloquist.

About forty years ago (1810), Dr. John Mason Good,[1] in some lectures delivered before the Surrey Institution of London, suggested that the larynx alone, by long and dexterous practice, and, perhaps, by a peculiar modification in some of its muscles or cartilages, may be capable of answering the purpose, and of supplying the place of the associate organs of the mouth. In confirmation of this view, he remarks, that, in singing, the glottis is the only organ made use of, except where the notes are articulated; and it is apparently the sole organ employed in the mock articulations of the parrot and other imitative birds; some of which have exhibited unusual powers. A parrot belonging to a Colonel O'Kelly, could, it is said, repeat twenty of the most popular English songs, and sing them to their proper tunes. The larynx, too, is the sole organ of all the natural cries; and hence, it has been imagined by Lord Monboddo[2] to have been the chief organ of articulate language, in its rudest and most barbarous state. "As all natural cries," he observes, "even though modulated by music, are from the throat and larynx, or knot of the throat, with little or no operation of the organs of the mouth, it is natural to suppose, that the first languages were, for the greater part, spoken from the throat; and that what consonants were used to vary the cries, were mostly guttural; and that the organs of the mouth would at first be but very little employed." Certain it is, that privation of the tongue does not necessarily induce incapacity of articulation; whether the defect be congenital, or caused after speech has been acquired. Professor John Thomson of Edinburgh found the speech but little impaired after bullets had carried away more or less of the tongue.[3] Under the Sense of Taste, several authentic cases were stated of individuals, who were deprived of this organ, and yet possessed the faculty of speech. To these we may add one other, which excited unusual interest at the time, and was examined under circumstances that could admit of no deception. The case forms the subject of various papers, by Dr. Parsons, in the Philosophical Transactions of London.[4] A young woman, of the name of Margaret Cutting, of Wickham Market, near Ipswich, in Suffolk, when only four years old, lost the whole of her

[1] Book of Nature, ii. p. 238, Lond., 1834; see also his Study of Medicine, Physiological Proem to Class ii., Amer. edit., i. 296, Philad., 1824.

[2] Origin and Progress of Language, i. 322, Edinb., 1773.

[3] Report of Observations made in the British Hospital, in Belgium, after the Battle of Waterloo, Edinb., 1816.

[4] Philosoph. Transact. for 1742 and 1747.

tongue, together with the uvula, from a cancerous affection; she still, however, retained the power of speech, taste, and deglutition without any imperfection; articulating as fluently and correctly as other persons; and even those syllables that commonly require the aid of the tip of the tongue for accurate enunciation. She also sang admirably; articulating her words whilst singing; and could form no conception of the use of a tongue in other people. Her teeth were few; and rose scarcely higher than the surface of the gums, owing to the injury to the sockets from the disease that had destroyed the tongue. The case, when first laid before the Royal Society, was attested by the minister of the parish, by a medical practitioner of repute, and by another respectable individual. The Society, however, were not satisfied, and appointed commissioners to inquire into the case, whose report coincided minutely with the first; and, to set the matter completely at rest, the young woman was shortly afterwards conveyed to London, and examined, in person, before the Royal Society.[1]

These cases are not so extraordinary as they appear at first sight; when we consider, that the tongue is not the sole organ of articulation, but that it shares the function with the various parts that compose the vocal tube. In reality, of the twenty-four articulate sounds, which our common alphabet comprises, there are few in which the tongue takes a distinct lead, as *l*, *d*, *t*, *r*, &c., though it is auxiliary to several others; but the guttural or palatine, *g*, *h*, *k*, *q;* the nasal, *m*, and *n;* the labial, *b*, *p*, *f*, *v;* and most of the dental, together with all the vowels, are little indebted to its assistance.

From these, and other concurrent facts, Dr. Good[2] concludes, that ventriloquism appears to be an imitative art, founded on a close attention to the almost infinite variety of tones, articulations, and inflexions, which the glottis is capable of producing in its own region alone, when long and dexterously practised upon; and in a skilful modification of these vocal sounds, thus limited to the glottis, into mimic speech, passed for the most part, and whenever necessary, through the cavity of the nostrils, instead of through the mouth. It is possible, he adds, though no opportunity has hitherto occurred of proving the fact by dissection, that they who learn this art with facility, and carry it to perfection, possess some peculiarity in the structure of the glottis, and particularly in respect to its muscles or cartilages. MM. Magendie[3] and Rullier,[4] however, affirm, that the quiescence of the lips, observed in the practised ventriloquist when enunciating, is more apparent than real; and that if he be capable of pronouncing without moving his lips, it is because he is careful to make use of words in which there are no labial consonants, or which do not absolutely require the movement of the lips in their formation. M. Rullier, indeed, denies positively, that the ventriloquist can speak without opening his mouth and moving his lips; but he affirms, that he uses his jaws, mouth, and lips, as little as possible in articulation; and he ascribes the common belief in their perfect quiescence to

[1] Elliotson's Human Physiology, p. 507, Lond., 1840. See a curious chapter on the Use of Tongues in Southey, The Doctor, vii. i., Lond., 1847.

[2] Op. citat.

[3] Précis, &c., i. 265.

[4] Art. Engastrimysme, in Dict. de Médecine, tom. viii., Paris, 1823.

the habit, acquired by him, of restraining their movements, united to the care he takes in concealing them; and of giving to his face an impassive expression, or one foreign to the verbal expression to which he is giving utterance.

On the whole, the explanation of Dr. Good appears the most satisfactory:—the larynx or glottis affords some individuals a facility in acquiring the art, which others do not possess, in the same manner as it makes some capable of singing, whilst others are forever incapacitated. It is probable, however, that there may be a greater degree of obscure action about the parts composing the vocal tube than Dr. Good is disposed to admit; and that this may be materially concerned in giving the voice its peculiar quality and intensity; and eliciting some of the sounds which might not be so easily produced by the action of the glottis alone. Sir David Brewster[1] observes, that when the ventriloquist utters sounds from the larynx without moving the muscles of his face, he gives them strength by a powerful action of the abdominal muscles; and Bennati affirms, that the ventriloquist uses chiefly the pharyngeal voice, of which mention will be made under the head of *Singing*.

Such is the history of the simple voice, as effected in the larynx. Articulate sounds may, however, be produced in the vocal tube alone. *Whistling*, for example, is caused by the expired air being broken or divided by the lips, which act the part of the lips of the larynx in the production of voice.

Whispering consists in articulating the air of expiration. It is wholly accomplished in the vocal tube; and, hence, the impracticability of singing in a whisper; singing being produced in the glottis.

The sound of *sighing* is produced by the rushing of air along the air passages, and especially along the vocal tube. In *laughing*, *crying*, and *yawning*, voice is concerned; but the physiology of these functions of expression will fall more appropriately under Respiration.

Having described the different views, that have been entertained, with regard to the production of voice, we shall now inquire into the function in connexion with expression. In this respect, it admits of division into the *natural* or *inarticulate voice*, and the *artificial* or *articulate*.

3. NATURAL OR INARTICULATE LANGUAGE.

This, which is sometimes termed the *cry* or *native* voice, is an inappreciable sound, entirely produced in the larynx, and requiring few or none of the organs of articulation to aid in its formation. As, however, it is caused by different degrees of contraction of the intrinsic muscles of the larynx, it is susceptible of a thousand different tones. It is elicited independently of all experience or education; seems to be inseparably allied to organization; and, consequently, occurs in the new-born infant, the idiot, the deaf from birth, and the wild man, if any such there be, as well as in the civilized individual. The natural voice differs as much as the sentiments it is employed to express. Each

[1] Letters on Natural Magic, p. 169, Amer. edit., New York, 1832.

moral affection has its appropriate cry;—the cry of joy is very distinct from that of grief;—of surprise from that of fear, &c.; and the pathologist finds, in the diseases of children more especially, that he can occasionally judge of the seat of a disease by the character of the cry, to which the little sufferer gives utterance; that there is, in the language of M. Broussais, a cry peculiar to the suffering organ.

By the cry, our vivid sensations are expressed, whether they be of the external or internal kind; agreeable or painful; and by it we exhibit all our natural passions, and most simple instinctive desires. Generally, the most intense sounds, to which the organ of voice can give utterance, are embraced in the natural cry; and, in its character, there is frequently something, that annoys the ear and produces more or less effect on those within hearing. It is, by its agency, that sympathetic relations are established between man and his fellows; and between animals of the same kind. The language, possessed by the greater part of animals, is this natural voice differing according to varying organization, and, therefore, instinctive; hence the various notes of birds; and the ranges, which we find the voice to possess in different species. Yet each species has one, by which it is distinguished and which it possesses, even when brought up in the same cage with one of another species; or when hatched, and attended to, by a foster mother endowed with very different vocal powers. In the case of a goldfinch and chaffinch, this has been put directly to the proof; and it is well known, that the cuckoo, which is never hatched or nurtured by its own parent, still retains the note, that has acquired it its name in almost every language of the globe. It is, probably, by this natural cry, and not by any signs addressed to the eye, that the process of pairing is effected, and that the female is induced to select her mate. The vocabulary of the common cock and hen is quoted as perhaps the most extensive of that of any tribe of birds with which we are acquainted; or rather, as Dr. Good remarks,[1] we are better acquainted with the extent of its range than with that of any other. The cock has his watchword for announcing the morning; his love-speech and terms of defiance. The voice of the hen, when leaving her nest, after laying, is different from that which she assumes when the brood is hatched, and both are very different from her cries, when her young are placed in jeopardy. Even the chick exhibits a variety in its voice, according to the precise emotion it experiences. All these sounds are such as the larynx of the animal alone admits of; and hence we can understand why, so far, they should be mere modifications of the natural voice; but it is more than probable, that the chick learns the adoption of a particular sound by the parent to express a particular emotion, as an affair of education. It can scarcely be conceived, that the clucking of the hen, when she meets with food proper for her offspring, can be understood at first by the chick. But as soon as it traces the connexion between the sound produced and the object of such sound, it comprehends the signification ever afterwards.

There are sounds, which, from their discordant and harsh characters,

[1] Book of Nature, ii. 277, Lond., 1826.

affect most animals perhaps independently of all experience. The cry of terror or pain appears to occasion sympathetically disagreeable effects on all that are within its sphere.

4. ARTIFICIAL OR ARTICULATE LANGUAGE.

Speech, likewise, is a vocal sound; but it is articulated, in its passage through the vocal tube; and is always employed to convey ideas, that have been attached to it by the mind. It is a succession of articulate sounds, duly regulated by volition, and having determinate significations connected with them.

The faculty of speech has been assigned by some philosophers chiefly to the organ of hearing. It is manifest, however, that this, like the musical ear, is referable to a higher organ. The brain must attach an idea to the impression made upon it by the sounds that impinge upon the organ of hearing; the sound thus becomes the *sign* of such idea, and is reproduced in the larynx at the will of the individual. Of the intellectual character of the process, we have decisive evidence. The infant of tender age has the ear and voice well developed, yet it is long before it is capable of speech; this does not happen until it discovers the meaning of the sounds addressed to it, and finds its own larynx capable of producing similar sounds, which can be made subservient to its wishes. It is thus, by imitation, that it acquires the faculty of speech. Again, the idiot, notwithstanding his hearing may be acute, and voice strong, is incapable of speech; and, in the maniacal and delirious, the language participates in the derangement and irregularity of ideas. The brain must, therefore, be regarded as the organ of the faculty of language; and the ear, larynx, and vocal tube as its instruments. Man, who is endowed with the most commanding intellect, has the vocal apparatus happily organized for expressing its various combinations; and, according to Gall, if the ourang-outang and other animals are incapable of speech, it is because they have not the intellectual faculty of language. In proof, that it is not to the vocal organ that this deficiency must be ascribed, he remarks, that animals may be made to enunciate several of the words of human speech, and to repeat them with music. The case of the far-famed parrot of Colonel O'Kelly has already been referred to. Mr. Herbert[1] saw this parrot, about the year 1799: it then sang perfectly about fifty different tunes, solemn psalms, and humorous or low ballads; articulating every word as distinctly as man, without a single mistake; beating time with its foot; turning round upon its perch, and marking the time as it turned. If a person sang part of a song it would take it up where he left off; and when moulting and unwilling to sing, turned its back and said, "Poll's sick." Gall, amongst other cases, cites that of a dog mentioned by Leibnitz, which could articulate some German and French words. This dog, of which Leibnitz was an "eye-witness," was at Zeitz, in Misnia. A young child had heard it utter some sounds, which it thought resembled German, and this led him to teach it to speak. At the end of about eight years, it had learned thirty words, some of which were, *tea*, *coffee*, *chocolate*, and *assembly*.

[1] In a note to the Rev. Gilbert White's Natural History of Selborne, p. 227.

It spoke only after its master had pronounced the word, and appeared to do so only on compulsion, although it was not ill used.[1] In the "Dumfries Journal," Scotland, for January, 1829, mention is made of a dog, then living in that city, which could utter distinctly the word "William," the name of the young man to whom it was much attached.[2] There is no doubt, however, that in numerous animals speech would be impracticable, owing to defective organization, even were they gifted with adequate intellect.

It is difficult—perhaps impossible—to say, how man came to select certain sounds as the types of certain intellectual acts; nor is it a matter which strictly concerns the physiologist. It may be remarked, however, that whilst some contend, that speech is a science which was determined upon, and inculcated, at an early period of the world, by one or more superior persons acting in concert, and inducing those around them to adopt their articulate and arbitrary sounds; others affirm, that it has grown progressively out of the natural language, as the increasing knowledge and wants of mankind demanded a more extensive vocabulary.[3] The first view is that of Pythagoras and Plato; but it was opposed by Lucretius and the Epicureans, on the ground, that it must have been impossible for any one person or synod of persons to invent the most difficult and abstruse of all human sciences with the paucity of ideas, and of means of communicating them, which they must have possessed; and that even allowing they could have invented such a science, it must still have been utterly impossible for them to teach it to the barbarians around them.

The opinions of those philosophers who confine themselves to the phenomena of nature, and hold themselves uncontrolled by other authority, accord with those of the Epicureans.

In the origin of language, it is probable, that words were suggested to mankind by sounds heard around;—by the cries of quadrupeds;—notes of the birds of the forest;—noises emitted by the insect tribe;—audible indications from the elements, &c. These, being various, probably first of all suggested discriminative names, deduced from the sounds heard. It is this imitation of the noise made by objects, that constitutes the figure of speech called *onomatopœia*,—the "*vox repercussa naturæ*" or "echo of nature," as Wachter[4] has defined it. Daily experience shows us, that this source of words is strictly physiological. Children designate a sonorous object by an imitation of the sounds rendered by it; and the greater number of sonorous bodies have had names, radically similar, given to them in languages differing most from each other. We say the serpents "*hiss;*" the bees "*hum;*" the storm "*blusters;*" the wind "*whistles;*" the hogs "*grunt;*" the hen "*cackles;*" the man "*snores,*" &c., words used, originally, not perhaps in these very shapes, but varying according to the varying idiom of language, to imitate the sounds elicited by those objects. Such words

[1] Letter to the Abbé Saint Pierre, Oper. ii. 180.
[2] Sharon Turner's Sacred History of the World, p. 280, Amer. edit., New York, 1832.
[3] Harris's Hermes, 3d edit., Book iii. p. 314, London, 1771; Beattie's Theory of Language, p. 246, London, 1803, and Good's Book of Nature, ii. 254, London, 1834.
[4] Glossarium Germanicum, Lips., 1737.

are numerous in all languages, and have been adopted to depict both the sound emitted, and the sonorous body itself; but, in some cases, the word imitating the sound has survived its transmission from language to language to the most modern times, whilst the name of the object whence it proceeded has experienced considerable mutation. The Sanskrit, the antiquity of which will not be contested, has a number of such words—as *wilala*, cat—*kukada*, hen—and *waihu*, wind; in the last of which the sound of the *w* (*oo*), imitates that of the passage of the air, and is found in the word corresponding to *wind*, (*ooind*,) in many languages. The Hebrew and the Greek have numerous phonetic words; but no language is richer, in this respect, than the Teutonic in all its ramifications, including the English. The animal kingdom affords us many examples, of which the following is one:—

Cuckoo.—This word is nearly the same in almost all languages. Greek, *κοκκυξ*; Latin, *cucullus*; Irish, *cuach*; Bask, *cucua*; Sclavonic, *kukulka*, *kukuscka*, &c.; Hungarian, *kukuk*; Hebrew, *cacatha*; Syriac, *coco*; Arabic, *cuchem*; Persian, *kuku*; Koriak, *kaikuk*; Kamtschadale, *kwakutschith*; Kurile, *kakkok*; Tartar, *kauk*; German, *kuckucks* or *guckguck*; Dutch, *koekoek*; whence our words *cuckoo* and *cuckold*, and the Scottish *gouckoo*, *gowk*, or *golk*; French, *cocu*; &c.

In the greater part of languages, words, expressive of the cries of animals, are accurate imitations. Of this, the following are a few examples.

Bleating of sheep.—Greek, *βληχαομαι*; Latin, *balare*; Italian, *belare*; Spanish, *balar*; French *bêler*; German, *blöken*; Dutch, *bleeten*; Saxon, *blætan*, &c.

Howling of wolves.—Greek, *ὀλολυζω*; Latin, *ululare*; German, *heulen*; Dutch, *huilen*; Spanish, *aullar*; French, *hurler*, &c. Hence the word *owl*.

Neighing of the horse.—Latin, *hinnire*; French, *hennir*; German, *wiehern*; Saxon, *hnægan*, &c.

Clocking or *clucking* of hens.—Latin, *glocire*; French, *glousser*; Greek, *κακκαζειν*; German, *glucken*; Dutch, *klokken*; Saxon, *clocran*, &c.

To *crow*, like a cock.—Greek, *κραζω*; German, *krähen*; Dutch, *kraayen*; Saxon, *craw*, &c., whence the word *crow*, the bird.

The Latin words *tinnimentum*, *tinnitus*, *tintinnabulum*, &c., from *tinnio*, "I ring," are all from the radical *tin*, and imitate the sound rendered on striking a metallic vessel. The *gurgling* of water; the *clanging* of arms; the *crash* of falling ruins; are of the same character; and the game *trictrac*, formerly *tictac*, seems to have been so called from the noise made in putting down the men or dice.

In whatever manner language was first formed, it is manifest that the different sounds could make but transient impression, until they were reduced to legible characters, which could recal them to mind. On our continent, the fact has often been noticed of a tribe of Indians separating themselves into two parties, and remaining distinct for years. In such case, the language has become so modified, that after the lapse of a considerable period they have scarcely been able to comprehend each other. Hence, the importance of the art of writing,—certainly the most valuable of human inventions. Of this, there have been two kinds, —*imitative* or *alphabetical*,—and *symbolical*, *allegorical*, or *emblematical*, the latter consisting of hieroglyphics, designs representing external objects, or symbolical allegories. The former, or the written representation of spoken sounds, alone concerns us. To attain this, every com-

pound sound has been reduced to certain elementary sounds, which are represented by signs, called *letters*. These elementary sounds, by combination, form *syllables*; and the syllables, by combination, *words*. The number of elementary sounds, admitted in each language, constitutes its *alphabet*, which differs more or less in certain languages; but as it is entirely a matter of human invention, and as the elementary sounds, of which the human voice is capable, are alike in the different races of mankind, we see readily, that the alphabets of the different languages must correspond, although the combinations of letters constituting syllables and words may vary essentially.

Into the origin of written legible language, it is not necessary to inquire. We may remark, that the invention has been considered so signally wonderful as to transcend human powers; and hence, St. Cyril, Clement of Alexandria, Eusebius, Isidore, and, in more modern times, Messrs. Bryant, Costard, &c., have been of opinion, that the knowledge of letters was first communicated to Moses by the Almighty himself, and that the decalogue was the earliest specimen of alphabetic writing. Many passages in the writings of Moses, show unequivocally, however, that written records must have existed prior to his time. In the passage in which writing is first mentioned in the sacred volume, the art is alluded to as one of standing:—"And the Lord said unto Moses, 'Write this for a memorial in a book or table;'" and in a subsequent chapter—"And thou shalt make a plate of pure gold, and grave upon, like the engravings of a signet, Holiness to the Lord."[1]

The English alphabet is considered to consist of twenty-six letters. It may, however, by ultimate analysis, be reduced to twenty-five simple sounds—A, B, D, E, F, G, H, I, J, K, L, M, N, O, P, R, S, T, U, V, Z, Ch, Sh, Th, and Ng. To these letters arbitrary names have been assigned, as *Bee* (B,) *See* (C,) *Dee* (D,) &c., which express very different sounds from those that belong to the letter when it forms part of a word or syllable. The word *bad* is not pronounced *bee-a-dee*, as the child, just escaped from learning his alphabet, must imagine; hence, he has to unlearn all that he has acquired; or to imagine, that different letters have very different sounds, according to the situation in which they are placed. To obviate this inconvenience, some persons are in the habit of teaching their children syllabically from the very first, by which they acquire the true sound attached to each letter of the alphabet. In the preceding enumeration of the simple sounds, that constitute the alphabet, C, Q, W, X, and Y, have been excluded, for the following reasons. C has always the sound of either S or K, as in *cistern* or *consonant*. Q has the sound of *koo*, as in quart, (*kooart;*) W of *oo*, as in word (*oourd;*) X of *ks*, or Z, as in vex, (*vecks,*) or Xerxes, (*zerkses;*) whilst Y has the sound of I or E, as in wry or yard, (*wri* or *eeard.*) *Ch*, *Sh*, and *Th*, have been added, as being true alphabetic or simple sounds.

Letters have been usually divided into two classes, *vowels* and *consonants*. The *vowels* or *vocal sounds* are so called, because they appear to be simple modifications of the voice formed in the larynx, uninter-

[1] Good, op. citat., ii. 273.

rupted by the tongue and lips, and passing entirely through the mouth. Such at least is the case with those that are reckoned *pure vowels*. These, in the English alphabet, are five in number,—A, E, I, O, and U. W and Y are, likewise, vowel sounds in all situations. In enunciating A, as in *fate*, the tongue is drawn backwards and slightly upwards, so as to contract the passage immediately above the larynx. In sounding E, the tongue and lips are in their most natural position without exertion. I is formed by bringing the tongue nearly into contact with the bony palate; O, by the contraction of the mouth being greatest immediately under the uvula, the lips being also somewhat contracted. In the production of U, the contraction is prolonged beneath the whole of the soft palate. From these principal vowels, all the other vowel sounds of the language may be formed, by considering them as partaking more or less of the nature of each. They are, in our language, fourteen in number: besides compound sounds, as in *oil* and *pound*. Of these fourteen, four belong to A; two to E; two to I; three to O; and three to U.

A, as in - - -	Fate. Far. Fast. Fall.	O, as in - - -	No. Not. Move.
E, as in - - -	Me. Met.	U, as in - - -	Tune. Tub. Bull.
I, as in - - -	Pine. Pin.		

The vowels are more easy of pronunciation than the consonants. They merely require the mouth to be opened; and howsoever it may be arranged in the enunciation of the different vowels, the vocal tube is simply modified, to vary the impression, which has to be made on the organ of hearing. The shape of the cavity is altered; but the passage of the air continues free, and the voice, consequently, issues in an unrestrained manner. Hence, perhaps, the physiological origin of the Danish word *Aa*, "a river"—a generic term, which became afterwards applied to three rivers in the Low Countries, three in Switzerland, and five in Westphalia,—the sound of the two broad A's flowing without obstacle, like a river. Time passes away in a similar manner; hence, for a like reason, the Greek ἀεὶ which signifies "always, perpetually;" and the German je, which has the same signification.

The consonants are more difficult of enunciation than the vowels; as they require different, and sometimes complex, and delicate movements of the vocal tube; and, on this account, they are not acquired so early by children. The term *consonant* is derived from one of its uses,—that of binding together vowels, and being sounded with them. By most, and according to Mr. Walker,[1] by the best grammarians, *w* and *y* are consonants when they begin a word; and vowels when they end one. Dr. Lowth,[2] however, a man of learning and judgment, who certainly would not suffer in a comparison with any of his opponents, regards them, as the author does, to be always vowels. Physiologically, it is not easy to look upon them in any other light. Yet Mr. Walker exclaims:—"How

[1] Preface to his Dictionary. [2] Introduction to English Grammar, p. 3.

so accurate a grammarian as Dr. Lowth could pronounce so definitely on the nature of *y*, and insist on its being always a vowel, can only be accounted for by considering the small attention which is generally paid to this part of grammar." No stronger argument, however, could be used against the useless expenditure of time on this subject, than the conclusion to which Mr. Walker himself has arrived; and for which he can find no stronger reasons, than that "if *w* and *y* have every property of a vowel, and not one of a consonant; why, when they begin a word, do they not admit of the euphonic article *an* before them?"!

The consonants are usually divided into *mutes*, *semi-vowels*, and *liquids*. Mutes are such as emit no sound without a vowel,—*b*, *p*, *t*, *d*, *k*, and *c* and *g* hard. *Semi-vowels* are such as emit a sound, without the concurrence of a vowel, as *f*, *v*, *s*, *z*, *x*, *g* soft or *j*. *Liquids* are such as flow into, or unite easily with, mutes, as *l*, *m*, *n*, *r*. These letters issue without much obstacle; hence perhaps their name.

In tracing the modes in which the different consonants are articulated, we find, that certain of them are produced by an analogous action of the vocal tube; so that the physiology of one will suffice for the other. For instance, the following nearly correspond:—

p	*f*	*t*	*s*	*k*	*ch*
&	&	&	&	&	&
b	*v*	*d*	*z*	*g*	*j*

B and P are produced when the lips, previously closed, are suddenly opened. B differs from P in the absence, in the latter, of an accompanying vocal sound. F and V are formed by pressing the upper incisor teeth upon the lower lip. They are, consequently, not well enunciated by the aged, who have lost their teeth. F differs from V only in the absence of an accompanying vocal sound. T and D are formed by pressing the tip of the tongue against the gums behind the upper incisor teeth. D is accompanied by a vocal sound; T not. S and Z are produced by bringing the point of the tongue nearly in contact with the upper teeth, and forcing the air against the edges of the teeth with violence. S differs from Z in the absence of the vocal sound. K and G are formed by pressing the middle of the tongue against the roof of the mouth, near the throat; separating the parts a little more rapidly to form the former, and more gently to form the latter of those letters. In K, the accompanying vocal sound is absent. Ch and J are formed by pressing *t* to *sh;* and *d* to *zh*. In Ch, there is no accompanying vocal sound. SH and ZH are formed in the same part of the tube as *s* and *z*. TH is formed by protruding the tongue between the incisor teeth, and pressing it against the upper incisors to produce its sound in *think*. Its sound in *that* is effected by pressing the tongue behind the upper incisor teeth. In the former case, it is unaccompanied by a vocal sound. In M, the lips are closed, as in B and P; and the voice issues by the nose. N is formed by resting the tongue against the gums, as in the enunciation of *t* and *d;* breathing through the nose with the mouth open. In L, the tip of the tongue is pressed against the palate, the sound escaping laterally. In forming the letter K, the middle and point of the tongue strike the palate with a vibratory motion; the tip being drawn back. Lastly, in the formation of H, the

breath is forced through the mouth, which is every where a little contracted. It need hardly be said, that the enunciation of these letters requires, that the vocal tube, or the parts concerned in the function, shall be in a sound condition.[1]

A few years ago, (1846,) an ingenious German, named Faber, exhibited publicly in Philadelphia a speaking automaton, in the construction of which he found that the alphabet can be simplified still further. The precise mechanism he did not unfold; but affirmed that the parts were made of elastic materials to resemble as nearly as possible the human vocal organs. These parts were susceptible of varied movements by means of keys. The author was much struck by the distinctness with which the automaton could enunciate various letters and words. The combination *three* was well pronounced; the *th* less perfectly; but astonishingly well. It also enunciated diphthongs and numerous difficult combinations of sounds. Sixteen keys were sufficient to produce all the sounds. It sang "God save the Queen" and "Hail Columbia"—the words and air combined.

The following is the alphabet of the automaton. 1. *Five simple vowels:* for example—*a* as in father; *o* as in home; *u* as in ruin; *i* as *e* and *e* as *a*. 2. *Nine consonants*, *l*, *r*, *w* (the German w—the English w is oo), *f*, *s*, *sh* in shall, and *b*, *d*, *g* hard, as in give. 3. A *nasal sound* and an *aspirate;* making in all sixteen simple sounds. From these the *compound sounds* are formed, as in the following examples: *b* and the *nasal* form *m; d* and the *nasal*, *n:* if the nasal sound be prevented, *me* becomes *be; not* becomes *dot; g* and the *nasal* form *ng; b* and the *aspirate* form *p; d* and the *aspirate*, *t; g* and the *aspirate*, *k; sh* and the *nasal*, *th; wf* or *uf* form *v; d* and *sh*, *j* and *g soft; t* and *sh*, *ch* in chin. The diphthongs admitted by Mr. Faber are *ai* i, *eu* u; and *au* sounded as in *how*.

Wolfgang von Kempelen,[2] in a work on the mechanism of human speech, which is considered classical in Germany,—and in which he treats of a speaking automaton (Sprachmaschine) of his invention,—divides the consonants into four classes. 1. *Mutes*, (ganz stumme,) as K, P, T. 2. *Explosives*, (Windmitlauter,) as F, H, Ch, S, and Sh. 3. *Vocal consonants*, (Stimmitlauter,) as B, D, G, L, M, and N; and 4. *Vocal Explosives*, (Wind und Stimmlauter zugleich,) as R, I, W, V, Z. Dr. Thomas Young has, likewise, divided the English consonants into classes; of which he enumerates five. 1. *Pure semi-vowels*, as L, R, V, Z, and J. 2. *Nasal semi-vowels*, as M and N. 3. *Explosive letters*, as B, D, and G. 4. *Susurrant letters*, as H, F, X, and S; and 5. *Mutes*, as P, T, K; but the most satisfactory classification, in a physiological, as well as philological point of view, is according to the parts of the vocal tube more immediately concerned in their articulation.

[1] See Mayo, Outlines of Human Physiology, 3d edit., p. 357, Lond., 1833; also, Haller, Element. Physiol., lib. ix. § 4, Lausan. 1766.

[2] Mechanismus der Menschlichen Sprache, s. 228, Wien, 1791; and Rudolphi, Grundriss der Physiologie, 2ter Band, 1ste Abtheil. s. 398, Berlin, 1823.

Labial.	Dento-labial.	Linguo-dental.	Linguo-palatal.	Guttural.
B M P	F V	Th	D J L N R S T Z Ch Sh Ng	G K

That this physiological arrangement has had much to do with the formation of congenerous tongues more especially is exhibited by facts connected with the permutation or change of letters;—when a word passes, for example, from one of the Teutonic or Romanic languages to another. "The changes of vowels," says Mr. Lhuyd,[1] "whether by chance or affectation, are so very easy and so common in all languages, that in etymological observations, they need not, indeed, be much regarded; the consonants being the sinews of words, and their alterations therefore the most perceptible. The changes of consonants also into others of the same class, (especially *labials*, *palatals*, and *linguals*,) are such obvious mistakes, that there is no nation where the common people in one part or other of their country do not fall into some of them." A few examples will show to what extent this permutation occurs between letters of the same class in different languages. In this view, we may regard the labials and dento-labials as belonging to the same.

P into B.—Greek, φλεψ; Latin, *phlebs*. Latin, (and Greek,) *episcopus*; English, *bishop*; Anglo-Saxon, *biscop*; German, b i s c h o f.

P into F and V.—Latin, *pater*; German, v a t e r; Dutch, *vader*; English, *father*.

T into S.—German, b e s s e r; English, *better*. German, w a s s e r; English, *water*.

D into Th.—German, d a s; Dutch, *dat*; English, *that*.

T into Z.—German, z u n g; Dutch, *tong*; English, *tongue*. German, z w e i g; English, *twig*.

L into R.—Spanish, *Gil Blas*; Portuguese, *Gil Bras*. Latin, *arbor*; Spanish, *albero*.

C or K into G.—Latin, *hemicranium*; French, *migraine*. Latin, *cibarium*; French, *gibier*. Latin, *acer*; Italian, *agro*. Latin, *alacer*; Italian, *allegro*. Greek, κυκνος; Latin, *cygnus*.

The most harmonious languages are such as have but few consonants in their words, compared with the number of vowels; hence the musical superiority of the Greek and Italian, over the English, German, &c. "Among certain northern nations," says M. Richerand,[2] "all articulated sounds appear to issue from the nose or the throat, and make a disagreeable pronunciation, doubtless because it requires greater effort; and he who listens, sympathizes in the difficulty, which seems to be felt by him that speaks;"—and he adds:—"would it not seem that the inhabitants of cold countries have been led to use consonants rather than vowels, because as the pronunciation does not require the same opening of the mouth, it does not afford the same space for the continual admission of cold air into the lungs?"! The whole of Richerand's remarks on this topic are singularly fantastic and feeble, and unworthy of serious discussion.

In regard to consonants, it has been presumed, that some common imitative principle must have existed with all nations, so as to cause them to conform in adopting such as produce a certain sound to convey

[1] Archæologia Britannica, Oxford, 1707.
[2] Elémens de Physiologie, edit. cit., p. 298.

the same effect to the ear. Dr. John Wallis[1] turned his attention to this matter, chiefly as regards the English language, and he has collected a multitude of examples to show, that a certain collocation of consonants at the commencement of a word generally designates the class of ideas intended to be conveyed by it. For instance, he remarks that:—

Str, always carries with it the idea of *great force* and *effort*:—as *strong*, *strike*, *stripe*, *strife*, *struggle*, *stretch*, *strain*, &c.

St, the idea of strength, but in less degree—the *vis inertiæ*, as it were:—as *stand*, *stay*, *stop*, *stick*, *stutter*, *stammer*, *stumble*, *stalk*, *steady*, *still*, *stone*, &c.

Thr, the idea of violent motion:—as *throw*, *thrust*, *throb*, *threat*, *throng*, &c.

Wr, the idea of obliquity or distortion:—as *wry*, *wreathe*, *wrest*, *wring*, *wrestle*, *wrench*, *wriggle*, *wrangle*, &c.

Br, the idea of violent—chiefly sonorous—fracture or rupture:—as *break*, *brittle*, *brust*, or burst, *brunt*, *bruise*, *broil*, &c.

Cr, the idea of straining or dislocation, chiefly sonorous:—as *crack*, *creak*, *crackle*, *cry*, *crow*, *crisp*, *crash*. Other words, beginning with these consonants, communicate the idea of curvature, as if from *curvus*:—as *crook*, *cringe*, *crouch*, *creep*, *crawl*, *cripple*, *crumple*, *crotchet*, &c. Others, again, denote decussation, as if from *crux*:—as *cross*, *cruise*, *crutch*, *crosier*.

Shr, the idea of forcible contraction:—as *shrink*, *shrivel*, *shrug*, *shrill*, &c.

Gr, the idea of the rough, hard, onerous and disagreeable, (either owing to the letter of roughness *r*, or from *gravis*,)—as *grate*, *grind*, *gripe*, *grapple*, *grieve*, *grunt*, *grave*, &c.

Sw, the idea of silent agitation or of gentle lateral motion:—as *sway*, *swag*, *swerve*, *sweat*, *swim*, *swing*, *swift*, &c.

Sm, a very similar idea to the last:—as *smooth*, *small*, *smile*, *smirk*, &c.

Cl, the idea of some adhesion or tenacity:—as *cleave*, *clay*, *cling*, *climb*, *cloy*, *cluster*, *close*, &c.

Sp, the idea of some dispersion or expansion, generally quick, (especially with the addition of the letter *r*,)—as *spread*, *spring*, *sprig*, *sprinkle*, *split*, *splinter*, *spill*, &c.

Sl, the idea of a gently gliding or slightly perceptible motion:—as *slide*, *slip*, *slippery*, *slime*, *sly*, *slow*, *sling*, &c.

Lastly: *Sq*, *Sk*, *Scr*, denote violent compression:—as *squeeze*, *squirt*, *squeak*, *squeal*, *skreek*, *screw*, &c.

Other interesting observations on the collocation of consonants, at the termination, and in the body, of words, are contained in the grammar of Wallis. His remarks, however, are chiefly confined to his own tongue. The President de Brosses[2] has taken a wider range, with a similar object, and endeavoured to discover why certain consonants, or a certain arrangement of consonants in a word, should designate certain properties, in all languages. Why, for instance, the *st* should enter into most words signifying firmness and stability:—as, in the Sanskrit, *stabatu*, to stand, *stania*, a town, &c.; in the Greek, στηλη, a column, στερεος, solid, immovable, στειρα, sterile, remaining constantly without fruit, στηριζω, "I fix firmly," &c.; in the Latin, *stare*, to stand; *stirps*, a stem; *stupere*, to be astonished; *stagnum*, stagnant water, &c.; and he might have added, in the German, still-stehend, stagnant; stadt, a town; stand, condition; sterben, to die; still-stand, cessation, &c., besides the English words, commencing with *st*, already quoted from Wallis. He farther inquires, why words, commencing with *sc*, denote hollowness, as σκαπτω, I dig; σκαφη, skiff or boat, in the Greek; *scutum*, a shield; *scyphus*, a large jug; *sculpere*, to engrave; *scrobs*, a ditch, in the Latin;—*ecuelle*, formerly *escuelle*, a dish; *scarifier*, to scarify; *scabreux*, scabrous; *sculpture*, &c., in the French; and simi-

[1] Grammatica Linguæ Anglicanæ, &c., edit. 6, Lond., 1765.

[2] Traité de la Formation Méchanique des Langues et des Principes Physiques de l'Etymologie, i. 199, Paris, 1765.

lar words might be added from our own language. *Ecrire*, formerly *escrire*, the French for "to write," is from the Latin *scribere;* and, anciently, a kind of style was used for tracing the letters in wax; which instrument, by a like analogy, was called, by the Greeks, σκαριφος. M. de Brosses[1] accounts for these, by supposing, that the teeth, being the most immovable of the organic apparatus of the voice, the firmest of, what he calls the dental letters, T, has been mechanically employed to denote stability; and to denote hollowness, the K or C has been adopted,—which are produced in the throat, the most hollow of the vocal organs. The letter S serves, he conceives, merely as an augmentative; as the sound can, by its addition, be made continuous. It is itself, however, a letter expressive of softness, when combined, as we have seen, with certain other consonants; or when employed alone at the commencement of a word.

In the same manner, the letters *fl* are used to designate the motion of fluids more especially,—as in the Greek, φλοξ, a flame; φλεψ, a vein; Φλεγεθων, a burning river in the infernal regions:—in the Latin, *flamma*, flame; *fluo*, I flow; *flatus*, wind; *fluctus*, wave, &c.:—in the German, flössen, to float; flöten, to play on the flute; fluss, a river; flug, flight, &c.; and in the French and English words of the same meaning. Lastly, the idea of roughness and asperity is conveyed by the letter *r*, as in the words *rough*, *rude*, *rock*, *romp*, &c. How different, for example, in smoothness are the two following lines, in which the S predominates, from those that succeed them, where the R frequently, and perhaps designedly, occurs:

> "Softly sweet in Lydian measures,
> Soon he soothed his soul to pleasures;"

And:—

> "Now strike the golden lyre again,
> A louder yet, and yet a louder strain;
> Break his bands of sleep asunder;
> And rouse him like a rattling peal of thunder."
>
> DRYDEN'S "*Alexander's Feast.*"

The foregoing remarks, suggested by those of Wallis and M. de Brosses, must not, however, be received too absolutely. In the condition in which we find languages at the present day, it would be impossible that they should hold good universally; but they will tend to show, that the physiology of the voice is intimately connected with this part of philology; and that the sounds emitted by the agency of particular parts of the vocal tube, may have led to the first employment of those sounds, according to the precise idea it may have been desired to convey;—gutturals, for example, for sounds conveying the notion of hollowness:—resisting dentals, that of obstacles, &c. The words *mamma* and *papa* are composed of a vowel and consonant, which are the easiest of enunciation; and which the child, consequently, pronounces and unites earlier than any other. Hence they have become the infantile appellations for *mother* and *father* with many nations. President de Brosses[2] affirms—and he has brought forward numerous examples to prove his position—that in all ages, and in every country, a labial, or, in default

[1] Op. cit., i. 261.

[2] Op. cit., i. 244.

of it, a dental, or both together, are used to express the first infantile words "papa" and "mamma;" but it is scarcely necessary to say, that the child, when it first pronounces the combinations, attaches no such meaning to them as the parent fondly imagines.

There is a rhetorical variety of onomatopœia, frequently considered under the head of *alliteration*, but by no means deriving its chief beauties from that source. It happens when a repetition of the same letter concurs with the sonorous imitations already described; as in the following line in one of the books of the Æneid of Virgil;—

"Luc*t*an*t*es ven*t*os *t*empes*t*a*t*esque sonoras,"

in which the frequent occurrence of the letter of firmness and stability, T, communicates the idea of the striking of the wind on objects.

In the "*Andromaque*" of Racine, a line of this character occurs:

"Pour qui sont ces serpens qui sifflent sur vos têtes,"[1]

in which the sound impressed on the ear has some similarity to the hissing of serpents: and in the "*Poème des Jardins*" of the Abbé Delille, there is the following example:—

"Soit que sur *l*e *l*imon une rivière *l*ente,
Dérou*l*e en paix les p*l*is de son onde indo*l*ente;
Soit qu'a t*r*ave*r*s les *r*ocs un to*rr*ent en cou*rr*oux
Se b*r*ise avec f*r*acas."[2]

In the first two lines, the liquid L denotes the tranquil flow of the river; whilst in the two last, the letter of roughness and asperity, R, resembles the rushing of the stream like a torrent. The remarks already made will have exhibited the radical difference in the ideas communicated by the sound of those letters, by the common consent of languages. In the German this variety of expression is often had recourse to; and by none more frequently than by the poet Bürger.[3] The English language affords a few specimens, but not as many as might be imagined. Of simple alliteration there are many; some that give delight; others that do violence to the suggestive principle; but there are comparatively few where the words are selected, which by their sound convey to the mind the idea to be communicated. The galloping of horses may be assimilated by a frequent succession of short syllables; slow, laborious progression by the choice of long; but in the onomatopœia in question, the words themselves must consist of such a collocation of one consonant, or of particular consonants, as adds force to the idea communicated by the words collectively. Of this, we have a good example in the lines before cited, in which the

[1] "For whom are those serpents that hiss o'er your heads?"

[2] Which may be translated as follows:—

"If o'er deep slime a river laves
In peace the folds of its sluggish waves;
Or o'er the rocks a torrent breaks
In wrath obstrep'rous."

[3] Art. Alliteration, and Onomatopœia, in Encyclopédie, par Diderot, D'Alembert, &c., and in Allgemeine Deutsche Real-Encyclopädie für die gebildeten Stände, (Conversations Lexikon,) Aufl. 8, Leipz., 1837.

repetition of the letter R, in the phonetic words, adds considerable force to the idea intended to be conveyed by the passage—

"Break his bands of sleep asunder;
And rouse him like a rattling peal of thunder,"

and in Byron's "Darkness,"

"Forests were set on fire—but hour by hour
They fell and faded—and the crackling trunks
Extinguish'd with a crash—and all was black."

5. SINGING.

The singing voice differs from other vocal sounds in consisting of appreciable tones, the intervals of which can be distinguished by the ear, and admit of unison. Under the sense of hearing we endeavoured to show, that the musical ear is an intellectual faculty; and that the ear is only the instrument for attaining a knowledge of sounds, which are subsequently reproduced by the larynx, under the guidance of the intellect. In this respect, therefore, there is a striking resemblance between music and spoken language.

Like the latter, singing admits of considerable difference, as regards intensity, timbre, &c. Voices are sometimes divided into the *grave* and *acute;* the difference between them amounting to about an octave. The former is the voice of the adult male; but he is capable of acute sounds, by assuming the *falsetto*, which M. Savart[1] conceives to be produced in the ventricles of the larynx; M. Bennati in the pharynx; and more recently, Mr. J. Bishop[2] has suggested, that it may arise either from the partial closing of the glottis, or from a nodal division of the vocal chords, "the pitch of the sound in the production of this peculiar modification of the voice being such, that the column of air in the vocal tube is of the precise length requisite to vibrate in unison with the larynx." The mode, however, in which the falsetto voice is produced is by no means determined. It has given rise to great diversity of views.[3] The acute voice is that of the grown female, children, and eunuchs. According to M. Pouillet,[4] the gravest sound of the male voice makes 190 vibrations per second; the most acute 678 per second; whilst the female voice makes 572 vibrations for the gravest, and 1606 for the most acute. By adding all the tones of an acute to those of a grave voice, they are found to embrace nearly three octaves; but, according to M. Magendie, it does not appear, that such a compass of voice, in pure and agreeable tones, has ever existed in one individual.[5] On the other hand, M. Biot calculated three octaves and a half to be the extreme range; this, Mr. Bishop[6] says, he knows from experience is too low an estimate. Independently of the falsetto, the compass of the natural voice would seem to rarely exceed two octaves; but in some cases, as in those of Catalani and Malibran, it has extended beyond

[1] Magendie's Journal de Physiologie, tom. v., Paris, 1825.
[2] Proceedings of the Royal Society, No. 65, London, 1847.
[3] Müller, Physiology, P. iv., p. 1032, Lond., 1838.
[4] Elémens de Physiologie Expérimentale, tom. iii. 130, Paris, 1832.
[5] Précis Elémentaire, i. 262.
[6] The Lond. and Edinburgh Philosophical Magazine, for October, 1836, p. 272.

three. Some singers can descend sixteen tones below, others can rise sixteen above, the medium. The former are called *tenor bass;* the latter *soprano;* but hitherto no example has occurred of a person, who could run through the thirty notes.

The musician establishes certain distinctions in the voice; such as *counter*, *tenor*, *treble*, *bass*, &c. We find it, also, differing considerably in strength, sweetness, flexibility, &c.[1]

The singing voice, according to M. Bennati,[2] is not limited to the larynx,—the pharynx being likewise concerned. The voice, produced in those two different parts, has long been termed *voce di petto*, and *voce di testa*. M. Bennati calls the former *laryngeal notes* or *notes of the first register;* the latter *supra-laryngeal* or *notes of the second register;* and M. Lepelletier designates them *laryngeal* and *pharyngeal* respectively;—comprising, in the dependencies of the pharynx, the tongue, tonsils, and velum palati, by means of which the latter class of sounds is elicited. The *laryngeal voice*, which is always more elevated by an octave in the female than the male, is most commonly met with. It furnishes the types called, 1. *Alt* or *soprano;* 2. *Counteralt;* 3. *Tenor;* 4. *Tenor Bass*. The pharyngeal voice presents only modifications of these types. It is met with in but few persons in its finest developement. It has usually been supposed to be formed by the superior ligaments of the larynx, or in the ventricles; but these gentlemen esteem it demonstrated, that it is formed at the guttural aperture, circumscribed by the base of the tongue, velum palati, its pillars, and the tonsils. By it is produced the *baritenor*, the *contraltino tenor*, and the *soprano sfogato*. Bennati concludes his memoir on the human voice by remarking,—that not only are the muscles of the larynx inservient to the modulation of the notes of song, but those of the os hyoides, tongue, and the superior, anterior, and posterior part of the vocal tube are called into action, without the simultaneous and properly associated operation of which the degree of modulation requisite for song could not take place.

When the voice is raised in the scale from grave to acute, a corresponding elevation takes place in the larynx towards the base of the cranium. By placing the finger on the pomum Adami, this motion can be easily felt; at the same time, the thyroid cartilage is drawn up within the os hyoides, and presses on the epiglottis; the small space between the thyroid and cricoid closes; the pharynx is contracted; the velum pendulum depressed and carried forwards; the tonsils approach each other; and the uvula is folded on itself. The reverse of these phenomena takes place during the descent of the voice.[3]

It has been already remarked, that the natural voice or cry is connected with the organization of the larynx. So far as it can be modified into tones independently of the participation of the intellect, a natural singing voice may be said to exist. To repeat, however, any song, requires both ear and intelligence; and, therefore, singing may be said

[1] Magendie's Jour. de Physiologie, x. 179.
[2] Recherches sur le Mécanisme de la Voix Humaine, Paris, 1832.
[3] Bishop and Bennati, in op. cit.

to have originated in social life. It can be employed, as it is in many of our operas, to depict the different intellectual and moral conditions,

"And bid alternate passions fall and rise."

When the air is accompanied by the words, or is articulated, we are capable of expressing, by singing, any of the thoughts or feelings, that can be communicated by ordinary artificial language.

Declamation is a kind of singing, except that the intervals between the tones are not entirely harmonic, and the tones themselves not wholly appreciable. With the ancients—it has been imagined—it differed much less from singing than with the moderns, and probably resembled the *recitative* of the operas. The ingenious work of Dr. James Rush of Philadelphia,[1] may be consulted on all this subject, with great advantage.

b. *Gestures.*

Under this appellation, and that of *muteosis*, are included those functions of expression, that are addressed to the sight and touch. It comprises not only the partial movements of the face, but also those of the upper extremities; besides the innumerable outward signs that characterize the various emotions. In many tribes of animals, the conventional language appears to be almost, if not entirely, confined to the gestures; and even in man—favoured beyond all animals in the facility of communicating his sentiments by the voice—the language of gestures is rich and comprehensive. It is in the gestures of the face chiefly, that he far exceeds other animals. This is, indeed, in him, the great group of organs of expression. In animals, the function is distributed over different parts of the body, the face assuming but little expression, whilst the animal is labouring under any emotion, if we make exception of the brute passion of anger and of one or two others. Hence it is, that, by some naturalists, man has been defined, by way of distinction, "a laughing and crying animal." In animals, almost all the facial expression of internal feeling is confined to the eye and mouth, but, in addition, the attitude of the body is variously modified, and the hair is raised by the panniculus carnosus, as we see on the back of the dog when enraged.

In the human countenance, alone, in the state of society, can the passions be read,—the rest of the body being covered by clothing; and even were it not, the absence of a coat of hair, and of a panniculus carnosus, would enable it to minister but little to expression. The skin of the face is very fine, and on certain parts, as the lips and cheeks, is habitually more or less florid, and admits of considerable and expressive variations in its degree of colour. The union of the different parts composing the face gives occasion to numerous reliefs, which are called *traits* or *features;* and beneath the skin are muscles, capable, by their contraction, of modifying the features in a thousand ways.

To comprehend fully the physiology of the facial expression of the

[1] Philosophy of the Human Voice, 3d edit., Philad., 1845.

Fig. 201.

Muscles of the Head and Face.

1. Frontal portion of occipito-frontalis. 2. Occipital portion. 3. Aponeurosis. 4. Orbicularis palpebrarum, which conceals corrugator supercilii and tensor tarsi. 5. Pyramidalis nasi. 6. Compressor nasi. 7. Orbicularis oris. 8. Levator labii superioris alæque nasi. The figure is placed on nasal portion. 9. Levator labii superioris proprius; the lower part of the levator anguli oris is seen between muscles 10 and 11. 10. Zygomaticus minor. 11. Zygomaticus major. 12. Depressor labii inferioris. 13. Depressor anguli oris. 14. Levator labii inferioris. 15. Superficial portion of masseter. 16. Its deep portion. 17. Attrahens aurem. 18. Buccinator. 19. Attollens aurem. 20. Temporal fascia which covers temporal muscle. 21. Retrahens aurem. 22. Anterior belly of digastricus muscle; the tendon seen passing through its aponeurotic pulley. 23. Stylo-hyoid muscle pierced by posterior belly of digastricus. 24. Mylo-hyoideus muscle. 25. Upper part of sterno-mastoid. 26. Upper part of trapezius. The muscle between 25 and 26 is the splenius. (Wilson.)

passions, a few observations on the muscles of the human face will be necessary. (Fig. 201.)

The *eyebrow* is greatly concerned in expression; and certain muscles are attached to it for the purpose of moving it. The fasciculus of fibres which descends from the *frontal muscle*, and is attached to the side of the nose, has been esteemed, by some, a separate muscle, and to have a distinct operation. It draws the inner extremity of the eyebrow downwards. When the *orbicularis palpebrarum*, and the last muscle act, there is a heavy lowering expression. If they yield to the action of the frontal muscle, the eyebrow is arched, and there is a cheerful, inquiring expression. If the *corrugator supercilii* acts, there is more or less of mental anguish, or of painful exercise of thought. If it combines with the frontalis, the forehead is furrowed, and there is an upward inflection of the inner extremity of the eyebrow, which indicates more of querulous and weak anxiety. "The arched and polished forehead," says Sir Charles Bell—of whose elegant and accurate *Essays*[1] the author will occasionally avail himself on this branch of the subject—"terminated by the distinct line of the eyebrow, is a table, on which we may see written, in perishable characters, but distinct while they continue, the prevailing cast of thought; and by the indications here, often the mere animal activity, displayed in the motions of the lower part of the face, has a meaning and a force given to it. Independent of the actions of the muscles, their mere fleshiness gives character to this part of the face. The brow of Hercules wants the elevation and form of intelligence; but there may be observed a fleshy fulness on the forehead, and around the eyes, which conveys an idea of dull brutal strength, with a lowering and gloomy expression, which accords with the description in the *Iliad*."

Sir Charles separates the *orbicularis palpebrarum* into two muscles;—the outer, fleshy, circular band, which runs round the margin of the orbit; and the lesser band of pale fibres, which lies upon the eyelids. The latter is employed in the act of closing the eyelids, but the former is only drawn into action in combination with the other muscles of the

[1] Essays on the Anatomy and Philosophy of Expression, 3d edit., Lond., 1844.

face in expressing passion, or in some convulsive excitement of the organ. In laughing and crying, the outer and more powerful muscle is in action, gathering up the skin about the eye, and forcing back the eyeball itself. In drunkenness, the power of volition over this muscle is diminished; and there is an attempt to raise the upper eyelid by a forcible elevation of the eyebrow.

The *muscles of the nostrils* are; 1st, *levator labii superioris alæque nasi*, which, as its name imports, raises the upper lip and nostril; 2dly, *compressor nasi*, a set of fibres which compress the nostril; and 3dly, *depressor alæ nasi*, which lies under *orbicularis oris*, and whose function is indicated by its name. The three muscles serve to expand and contract the opening or canal of the nostril, moving in consent with the muscles of respiration, and thus the inflation of the nostrils indicates general excitement, and animal activity.

The muscles of the lips are; 1st, *levator labii proprius*, which raises the upper lip; 2dly, *levator anguli oris*, which raises the angle of the mouth; and 3dly, the *zygomatic muscle*, which is inserted into the angle of the mouth. Sometimes an additional muscle of the name exists:—*zygomaticus minor*. These last muscles raise the upper lip and angle of the mouth, so as to expose the canine teeth. If they be in action contrary to the orbicularis oris, there is a painful and bitter expression; but if they be influenced along with the orbicularis oris, and orbicularis palpebrarum,—if the former of these muscles be relaxed, and the latter contracted,—there is a fulness of the upper part of the face, and a cheerful, smiling expression of countenance. The *orbicularis oris* closes the mouth; and, when allowed to act fully, purses the lips. The *nasalis labii superioris* draws down the septum of the nose. The *triangularis oris* or *depressor labiorum* indicates, by its name, its function. The *quadratus menti* is a depressor of the lower lip. The *levatores menti*, by their action, draw up the chin, and project the lower lip; and the *buccinator* is chiefly for turning the alimentary bolus in the mouth; and, in broad laughter, retracts the lips. The orbicularis muscle is affected in the various emotions of the mind; trembling and relaxing in both grief and joy: it relaxes pleasantly in smiling.

The union of these various muscles at the angle of the mouth produces the fleshy prominence noticed in those who have thin faces; and who are, at the same time, muscular. When the cheeks are fat and full, the action of these muscles produces the dimpled cheek. The angle of the mouth is full of expression, according as the orbicularis, or the superior or inferior muscles inserted into it have the preponderance.

Lastly; the *temporal* is a strong muscle, which raises the lower jaw. It is assisted by the *masseter*, a deep-seated muscle, which lies on the outside of the lower jaw; arises from the jugum, and is inserted into the angle of the jaw.

Two different nerves are distributed to these muscles,—the fifth pair, and portio dura or facial of the seventh; the latter of which, according to the experiments of Sir Charles Bell, is concerned in the instinctive movements of expression; and comparative anatomy exhibits, that the number and intricacy of these nerves vary in proportion to the animal's

Fig. 202.

Distribution of Facial Nerve.

1. Facial nerve, escaping from stylo-mastoid foramen, and crossing ramus of lower jaw; the parotid gland has been removed in order to see the nerve more distinctly. 2. Posterior auricular branch; the digastric and stylo-mastoid filaments are seen near origin of this branch. 3. Temporal branches, communicating with (4) branches of frontal nerve. 5. Facial branches communicating with (6) infra-orbital nerve. 7. Facial branches, communicating with (8) mental nerve. 9. Cervico-facial branches communicating with (10) superficialis colli nerve, and forming a plexus (11) over submaxillary gland. Distribution of branches of the facial in a radiated direction over side of face constitutes the *pes anserinus*. 12. Auricularis magnus nerve, one of ascending branches of cervical plexus. 13. Occipitalis minor, ascending along posterior border of sterno-mastoid muscle. 14. Superficial and deep descending branches of cervical plexus. 15. Spinal accessory nerve, giving off a branch to external surface of trapezius muscle. 16 Occipitalis major nerve, posterior branch of second cervical nerve.

power of expression. The nerves of the face and neck of the monkey are numerous, and have frequent connexions; but on cutting the seventh pair, or *respiratory nerve of the face* of Sir Charles Bell's system, the features are found to be no longer influenced by the passions. Yet the skin continues sensible, and the muscles of the jaws and tongue are capable of the actions of chewing and swallowing. If the respiratory nerve of one side be cut, the expression of that side is destroyed; whilst the chattering, grinning, and other movements of expression continue on the other. In a dog, too, if the respiratory nerve of the face be cut, he will fight as bitterly, but with no retraction of his lips, sparkling of the eye, or drawing back of the ears. The face is inanimate, although the muscles of the face and jaws, so far as they are liable to be influenced through other nerves, continue their office. The game-cock, in the position of fighting, spreads a ruff of feathers around his head. The position of his head and the raised feathers are the expressions of hostile excitement; but on the division of the respiratory nerve, the feathers are no longer raised, although the pugnacious disposition continues. It has been found, moreover, that if the galvanic influence be passed from one divided extremity of the respiratory nerve to the other, the facial expression returns; and, in certain cases of incomplete hemiplegia, in which the movements of expression of the face were alone rendered impracticable, the disease was found to have implicated only the respiratory or facial nerve. The views of Sir Charles Bell regarding the connexion alleged by him to subsist between the seventh pair and the associated movements of respiration have, however, been contradicted by the experiments of Mr. Mayo,[1] and his inferences regarding the fifth pair as being jointly a nerve of sensation and of voluntary motion have been considered to require qualification. By dividing the

[1] Outlines of Human Physiology, 4th edit., p. 254, London, 1837.

portio dura of the seventh pair in the ass, and on both sides instead of one, as done by Sir Charles Bell, Mr. Mayo found, that the nerve presides over simple voluntary motion only; and by a similar division of the second and third branches of the fifth, at their points of convergence, he showed, that the lips were deprived of sensation, not of motion. "No doubt, I believe," says Mr. Mayo, "is now entertained, that the inference which I drew from these experiments is correct;—namely, that the portio dura of the seventh pair is a simple voluntary nerve, and that the *facial branches* of the fifth are exclusively sentient nerves." In the prosecution of his inquiries, Mr. Mayo ob-

Fig. 203.

Plan of the Branches of the Fifth Nerve, modified from a sketch by Sir C. Bell.

a. Submaxillary gland, with the submaxillary ganglion above it. 1. Small root of the fifth nerve, which joins the lower maxillary division. 2. Larger root, with the Gasserian ganglion. 3. Ophthalmic nerve. 4. Upper maxillary nerve. 5. Lower maxillary nerve. 6. Chorda tympani. 7. Facial nerve.

served, that the masseter muscle, temporal, pterygoids, and circumflexus palati receive no branches from any nerve except the fifth, and yet that they receive no twigs from the ganglionic portion of the nerve; and thence he concludes, that almost all the branches of the large or ganglionic portion of the fifth pair are nerves of sensation, whilst those of the small fasciculus or *ganglionless* portion are nerves of motion. This smaller portion of the fifth pair issues from the peduncles of the brain; constitutes a gangliform plexus with the inferior maxillary only; presents the common aspect of most nerves of the body, and is distributed to the chief muscles concerned in the process of mastication. Hence

it was termed by Bellingeri[1] *nervus masticatorius;* and by Sir Charles Bell, long afterwards, *motor* or *manducatory portion of the fifth nerve.* To this smaller fasciculus of the fifth, twigs from the ganglionic portion of the nerve are distributed. The ganglionless portion, and portio dura of the seventh, Mr. Mayo conceives to be voluntary nerves to parts, which receive sentient nerves from the larger or ganglionic portion of the fifth. The facial nerve, however, after it has passed through the parotid gland, becomes sensory also, owing to its having received a twig from the fifth pair.

Pathology affords numerous examples of injury done to the facial nerve. In some of these, the nerve itself may be in a morbid condition in a portion of its course; in others, the part of the encephalon, whence the nerve originates, may be the seat of the lesion. The prognosis will, of course, vary according to the seat; but, as a general rule, paralysis of the facial nerve is not of great moment. The author has seen several cases of partial paralysis of this kind; some of which have wholly disappeared; but in others the loss of power appears to be permanent. In a case, which presented itself to him in the Baltimore Infirmary, the mischief was probably seated near the origin of the nerve, as it resulted from serious injury to the head. A carriage-horse, belonging to a friend, by exerting considerable power, forced its head through an aperture in the partition of the stall, and was unable to withdraw it, in consequence of the under jaw catching the sides of the aperture. During the efforts to extract it, so much pressure was made upon the portio dura of one side, that the animal lost all power of expression in the corresponding side of the head; the soft parts about the mouth dropped, and the ear no longer associated with that of the opposite side in expression; yet the movements of mastication and deglutition were scarcely affected. This state of paralysis continued for a few days, and gradually disappeared. Fig. 204 represents a case of paralysis of this nerve, produced

Fig. 204.

Paralysis of the Facial Nerve. (Marshall Hall.)

[1] Dissert. Inaugur., Turin., 1823; cited in Edinb. Med. and Surg. Journ., July, 1824.

by the pressure of a tumour beneath the ear: the orbicularis palpebrarum was paralysed so that the patient was unable to close his eyelids.

Independently of the various muscular actions which modify the expression of the human countenance, there are certain others that mark the different mental emotions. The skin varies in colour, becoming pale or suffused, and frequently alternating rapidly between these two conditions. The changes are more especially witnessed on the forehead, cheeks, and lips; and arise from an augmented or diminished flow of blood into the capillaries of the part, under the influence of the existing emotion. Under such circumstances, the eye may participate in the suffusion. The skin may, also, vary in its degree of moisture or heat; it may be dry, or bathed in perspiration; and the perspiration may be warm or cold;—the two conditions occasionally alternating. Particular parts of the face, again, are more susceptible of this "sweat of expression," as it has been termed,—the forehead and temples for example. The heat of the head is also occasionally modified; a sudden glow is felt in the countenance; and the expression is sometimes evident to a second person.

The expression of the human eye, connected with the action of the oblique muscles, has been referred to under Vision. It was there asserted, that in insensibility, the organ, it has been presumed, is given up to the action of the oblique muscles, and is drawn up under the upper eyelid. The eye itself is, however, capable of various expressions, depending upon varied positions of its tutamina; and especially of the secretion from its mucous covering—the conjunctiva,—and from the lachrymal gland; so that it may be *swimming*, or the tears may flow over the cheeks and constitute *weeping*.

In addition to these, which may be esteemed sources of expression in the human countenance, may be added the action of *osculation* or *kissing*; which, wherever practiced, is employed as an expression of love and friendship;—confined with us to those of the female sex, or of opposite sexes; but, in some countries, employed as an expression of regard between males also.

It is impracticable to describe all the facial expressions—*Prosoposis*, as they have been collectively termed—of which the human countenance is susceptible. They are commonly classed under two heads; the *exhilarating*, in which the face is flushed, and the countenance expanded;—the muscles being contracted from within to without; and the *depressing*, in which, on the contrary, the face is pale, and the features are drawn inwards and sunken.

Let us inquire into the physiology of a few of these expressions; beginning with the play of the features in broad *laughter*, (Fig. 205,) as being, perhaps, the most easy of explanation. In laughing, it is in vain that we endeavour to confine the lips; a complete relaxation of the orbicularis oris gives uncontrolled power to the opponent muscles inserted into the angles of the mouth and upper lip. Hence, the lateral retraction of the angles of the mouth; the elevation of the upper lip disclosing the teeth; the peculiar elevation of the nostrils without their being expanded, and the dimple of the cheek, where the acting muscles congregate: hence, also, the fulness of the cheeks, rising so as

Fig. 205.

Broad Laughter. (Sir Charles Bell.)

to conceal the eye, and throw wrinkles about the lower eyelids and temples. In this expression, the whole of the movable features are raised upwards. The orbicularis palpebrarum does not partake of the relaxation of the orbicularis oris. It is excited, so as to contract the eyelids, and sink the eye, whilst the struggle of a voluntary effort of the muscles to open the eyelids, and raise the eyebrow, gives a twinkle to the eye, and a peculiar obliquity to the eyebrow, the outer part of which is most elevated. At the same time, the individual holds his sides to control the contractions of the muscles of the ribs. The diaphragm is violently agitated. The same influence spreads to the throat, and the sound of laughter is as distinct as the signs in the face.

Fig. 206.

Faun Weeping. (Sir Charles Bell.)

In this movement of expression we have an instance of the associated action of different parts, which are considered to be under the influence of the respiratory system of nerves of Sir Charles Bell. The facial expression is under the direction of the portio dura or respiratory nerve of the face.

In the face of a faun, (Fig. 206,) sketched by Sir Charles Bell, we have the expression of *weeping* from pain. In the violence of weeping, accompanied with lamentation and outcry, the face is flushed or suffused from stagna-

tion of blood in the vessels. The muscles of respiration are affected from the commencement, and the return of blood from the head is somewhat impeded. The muscles of the cheeks are in movement. Those that depress the angles of the mouth are powerfully contracted, and the orbicularis oris is not relaxed, but drawn open by the predominant action of its opponents. A convulsive movement in the muscles about the eyes attends; the eyebrow is drawn down; the eyes are compressed by the eyelids; the cheek is raised; the nostril drawn out, and the mouth stretched laterally. In weeping, also, unless the convulsive movement of the muscles is very strong, the expression of grief affects that part of the eyebrows next the nose. It is turned up with a peevish expression, which corresponds with the depression of the corners of the mouth. This depression gives an air of despondency and languor to the countenance, when accompanied by general relaxation of the muscles. When the corrugator cooperates, there is mingled in the expression something of mental energy, moroseness, or pain. If the frontal muscle unites its action, an acute turn upwards is given to the inner part of the eyebrow, very different from the effect of the general action of the frontal muscle, and characteristic of anguish, debilitating pain, or discontent, according to the prevailing cast of the rest of the countenance. The depression, however, of the angle of the mouth, that indicates languor and despondency, must be slight; as the depressor anguli oris cannot act forcibly, without the action of the superbus participating—a muscle, which quickly produces a revolution in the expression, and makes the under lip pout contemptuously.

The expression at the angles of the mouth demands the careful study of the painter; the most opposite characters being communicated to the countenance by their elevation or depression. When Peter of Cortona was engaged on a picture of the iron age for the royal palace of Pitti, Ferdinand II., who often visited him, and witnessed the progress of the piece, was particularly struck with the exact representation of a child in the act of crying. "Has your majesty," said the painter, "a mind to see how easy it is to make this very child laugh?" The king assented: and the artist, by merely elevating the corner of the lips and inner extremity of the eyebrows, made the child, which at first seemed breaking its heart with weeping, seem equally in danger of bursting its sides with immoderate laughter, after which, with the same ease, he restored to the figure its proper expression of sorrow.[1]

It is at the angle of the mouth and the inner extremity of the eyebrow, that the expression which is peculiarly human is situate. These are the most movable parts of the face. On them the muscles are concentrated, and it is upon their changes that expression is acknowledged chiefly to depend. All the parts, however, of an impassioned countenance are in accordance with each other. When the angles of the mouth are depressed in grief, the eyebrows are not elevated at the outer angles as in laughter. When a smile plays around the mouth, or when the cheek is elevated in laughter, the eyebrows are not ruffled as in

[1] Good's Book of Nature, iii. 291, Lond., 1834.

grief. In real emotion, these opposite actions cannot be combined; and, when united by the mimic, the expression is farcical and ridiculous.

Dr. Wollaston[1] has shown, that the same pair of eyes may appear to direct themselves either to or from the spectator, by the addition of other features in which the position of the face is changed. The nose principally produces the change of direction, as it is more subject to change of perspective than any other feature; and Dr. Wollaston has shown, that even a small portion of the nose will carry the eyes along with it. He obtained four exact copies of the same pair of eyes looking at the spectator, by transferring them upon copper from a steel plate, and having added to each of two pairs of them a nose—in one case directed to the right, and in the other to the left, and to each of the other two pairs a very small portion of the upper part of the nose—all the four pairs of eyes lost their front direction, and looked to the right or to the left, according to the direction of the nose, or of the portion of it that was added. But the effect thus produced is not limited to the mere change in the direction of the eyes; for a total difference of character may bc given to the same eyes by a due representation of the other features. A lost look of devout abstraction in an uplifted countenance may be exchanged for an appearance of inquisitive archness in the leer of a younger face turned downwards and obliquely towards the opposite side. This, however, as Sir David Brewster has remarked, is not perhaps an exact expression of the fact. The new character, which is said to be given to the eyes, is given only to them in combination with the new features; or what is probably more correct, the inquisitive archness is in the other features, and the eye does not belie it. Sir David adds, that Dr. Wollaston has not noticed the converse of these illusions, in which a change of direction is given to fixed features by a change in the direction of the eyes. This effect is seen in some magic lantern sliders, where a pair of eyes is made to move in the head of a figure, which invariably follows the motion of the eyeballs.

In *bodily pain*, the jaws are pressed together, and there is grinding of the teeth; the lips are drawn laterally, so as to expose the teeth and gums; the nostrils are distended to the utmost, and at the same time drawn up; the eyes are largely uncovered, and the eyebrows elevated; the face is turgid with blood, and the veins of the temple and forehead are distended; the breath being suspended, and the descent of the blood from the head impeded.

In *anguish*, conjoined with *bodily suffering*, the jaw falls, the tongue is seen; and, in place of the lateral retraction of the lips, the lower lip falls; the eyebrows are knit, whilst their inner extremities are elevated; the pupils of the eyes are in part concealed by the upper eyelids, and the nostrils are agitated. Agony of mind is here added to the bodily suffering, which is particularly indicated by the change in the eyebrow, and forehead.

[1] Philosophical Transact. for 1824, p. 247; see, also, Letters on Natural Magic, by Sir D. Brewster, Amer. edit., p. 115, New York, 1832.

In *rage*, the features are unsteady; the eyeballs are largely seen, roll, and are inflamed. The forehead is alternately knit and raised in furrows by the motion of the eyebrows; and the nostrils are inflated to the utmost; the lips are swelled, and, being drawn, open the corners of the mouth. The action of the muscles is strongly marked. The whole countenance is at times pale; at others, inflated, dark and almost livid; the words are passed forcibly through the fixed teeth, and the hair is on end.

Fear has different degrees. Mere *bodily fear* resembles the mean anticipation of pain. The eyeball is largely uncovered; the eyes are staring, and the eyebrows elevated to the utmost stretch. To these are added a spasmodic affection of the diaphragm and muscles of the chest, which affects the breathing, and produces a gasping in the throat, with an inflation of the nostrils, convulsive opening of the mouth, and dropping of the jaw;—the lips nearly concealing the teeth, yet allowing the tongue to be seen, and the space between the nostril and lip being full. There is a hollowness and convulsive motion of the cheeks, and a trembling of the lips and muscles on the sides of the neck. The lungs are kept distended; and the breathing is short and rapid. The surface is pale from the recession of blood; and the hair is lifted up by the creeping of the skin. In fear, where the apprehended danger is more remote, but is approaching, the person trembles and looks pale; a cold sweat is on the face; the scream of fear is heard; the eyes start forward; the lips are drawn wide; the hands are clenched, and the expression becomes more strictly animal, and indicative of such fear as is common to brutes.

In *terror* or that kind of fear in which the mind participates more there is a more varying depression in the features, and an action of those muscles, which are peculiar to man, and seem to indicate his superior intelligence and mental feeling. The eye is bewildered; the inner extremity of the eyebrows is turned up, and strongly knit by the action of the corrugator and orbicular muscles; and distracting thoughts, anxiety and alarm are strongly indicated by this expression, which does not belong to animals. The cheek is slightly elevated, and all the muscles, that concentrate about the mouth, are in action.

In *admiration*, the forehead is expanded and unruffled; the eyebrow gently raised; the eyelid lifted so as to expose the coloured circle of the eye, whilst the lower part of the face is relaxed into a gentle smile. The mouth is open; the jaw is a little fallen; and, by the relaxation of the lower lip, we just perceive the edge of the lower teeth and the tongue.

In *joy*, the eyebrow is raised moderately, but without any angularity; the forehead is smooth; the eye full, lively and sparkling; the nostril moderately inflated, and a smile is on the lips.

This subject is, however, interminable. Enough has been stated to exhibit the anatomy of the varying characters of facial expression. It will be found beautifully treated and illustrated in the work of Sir Charles Bell, to which reference has been made.

From all that has been said, it is evident, that the countenance is a good general index of the existing state of the feelings; but farther

than this it cannot be depended upon. Yet, in all ages, it has been regarded as the index of individual character. Allusion has been made to the estimate of personal character from the shape of the head, as described by the older poets. Similar indications were conceived to be deducible from the form of the face, expression of the eyes, &c. Thus Shakspeare:—

> *Cleopat.* "Bear'st thou her face in mind? is't long or round?
> *Messeng.* Round, even to faultiness.
> *Cleopat.* For the most part, too,
> They are foolish that are so. Her hair, what colour?
> *Messeng.* Brown, madam, and her forehead
> As low as she would wish it."
>
> ANTONY AND CLEOPATRA, iii. 3.

And again:—

> "Which is the villain? Let me see his eyes,
> That when I note another man like him,
> I may avoid him."
>
> MUCH ADO ABOUT NOTHING.

John Baptist Porta[1] and Lavater[2] have endeavoured to establish a "science," by which we can be instructed, how to discover the secret dispositions of the head and heart from the examination of particular features. The latter enthusiast, in particular, appears to have carried his notions to the most chimerical extent. "No study," he remarks, "excepting mathematics, more justly deserves to be termed a *science* than *physiognomy*. It is a department of physics including theology and belles lettres, and in the same manner with these sciences may be reduced to rule. It may acquire a fixed and appropriate character. It may be communicated and taught." In another place, he remarks, that no person can make a good physiognomist unless he is a well-proportioned and handsome man;[3] yet he himself was by no means highly favoured in these respects; and it is difficult to say, according to his own theory, how he obtained such progress in the "*science!*"

There is one case, and perhaps, one only, in which physiognomy can aid us in the appreciation of character. It has been remarked, that the facial expression may accurately depict the existing emotion. If, therefore, any passion be frequently experienced, or become habitual, its character may remain impressed upon the countenance, and admit of an opinion being formed of the individual. No one, who has seen the melancholy mad, can mistake the piteous expression produced by brooding over the corroding idea that engrosses him. In the sketch (Fig. 207), from Sir Charles Bell,[4] we have the testy, peevish countenance, bred of melancholy; of one who is incapable of receiving satisfaction from whatever source it may be offered, and who "cannot endure any man to look steadily upon him, even to speak to him, or laugh, or jest, or be familiar, or hem, or point, without thinking himself contemned, insulted, or neglected." Such a countenance no one can misapprehend.

[1] La Physiognomie Humaine de Jean Baptiste Porta, Rouen, 1655.
[2] Works, from the French, by G. Grenville, Esq., Lond.; or Précis Analytique et Raisonné du Système de Lavater, par N. J. Ottin, Bruxelles, 1834.
[3] Good's Book of Nature, iii. 309, Lond., 1834.
[4] Anat. of Expression, edit. cit.

Fig. 207.

Physiognomy of Melancholy. (Sir Charles Bell.)

In lesser degrees, particular features are found bearing, or seeming to bear, the impress of particular emotions; and, accordingly, we are in the daily habit of forming opinions at first sight, both of the intellectual and moral characteristics of individuals, by the expression of the countenance. Of course, we are frequently led into error; inasmuch as habitual feelings alone are indicated by the physiognomy, whilst the natural disposition may be of an opposite character. The fallaciousness of this mode of judging of mankind has been proverbial in all times. Whenever we attempt to decide upon a man's intellectual powers by the rules laid down by Lavater we are constantly deceived; and, in this respect, he has himself evidently fallen into gross errors.

What may be, not inappropriately, styled "*medical physiognomy*," or the changes of features indicative of, and peculiar to, different diseases and stages of disease, is a subject of moment, and has not met with sufficient attention. In diseases of infancy in particular, the appearance of the countenance often materially aids us in discriminating their seat. There is a marked difference between the facial expression of one labouring under violent pain in the head, and of one suffering from excruciating pain in the abdomen, even in the adult. Less degrees of pain are, of course, disregarded; and it is only in severe cases, that physiognomy can be inservient to diagnosis; but in the infant, which readily gives expression to pain or uneasiness, the countenance is an excellent medium of discrimination, and frequently indicates, at the first glance, the seat of the derangement. The character, too, of the countenance, in serious disease, as to anxiety, convulsion, &c., is often a subject of watchful interest with the physician.[1] Mute expression is

[1] See, on special medical physiognomy, M. Jadelot, cited by M. de Salle, in Traité des Maladies des Enfans de Michael Underwood, &c., p. 36 et seq.; and in the author's Commentaries on Diseases of the Stomach and Bowels, p. vii., Lond., 1824.

not, however, restricted to the face, although, as already remarked, in civilized man, whose nakedness is covered, we are shut out from the observation of many acts of this nature. During emotion, the skin covering the body may participate with that of the face in its changes from pale to red; and it may be warm or cold; dry or bathed in perspiration; or, during particular depressing passions, may creep and exhibit the rough character of the *cutis anserina* or *goose skin*. Under special emotions, the erectile tissues of the organs of generation, and of the nipple in the female, experience turgescence. All these changes are more or less concealed from view. We are, therefore, more familiar with the sight of phenomena of expression, that affect the whole body, as regards its different attitudes and modes of progression. How tremulous and vacillating is the attitude of one labouring under fear; and how different the port of the meek and lowly from that of the proud and haughty! In walking, we observe a similar difference; and can frequently surmise the passion, whether exhilarating or depressing, under which a person, at a distance, may be labouring, from the character of his progression.

> "You may sometimes trace
> A feeling in each footstep, as disclosed
> By Sallust, in his Catiline, who, chased
> By all the demons of all passions, showed
> Their work even by the way in which he trode."—BYRON'S "*Don Juan*."

Again, on the communication of sudden tidings of joy, we feel a desire to leap up, and give way to the most wild and irregular motions; whilst the shrinking within ourselves, as it were, and the involuntary shudder, sufficiently mark the reception of a tale of horror.

Properly speaking, the subject of cranioscopy belongs to the function of expression, but it has already been considered under another head.

Many of the partial movements constitute an important part of the language of expression, especially with the savage, and with those unfortunates who are debarred the advantages of spoken language. In almost all nations, the motions of the head on the vertebral column are used as signs of affirmation or negation;—the former being indicated by a sudden and short forward flexion of the head on the column; the latter, by a rapid and short rotation on the axis or vertebra dentata. The shoulders are shrugged in testimony of impatience, contempt, &c. The upper extremities are extensively employed as a part of conventional language, and were probably used for this purpose before speech was invented. The open and the closed hands communicate different impressions to the observer; the pointed finger directs attention to the object we desire to indicate, &c. When persons are at such a distance from each other, that the voice cannot be heard, this is the only language they can have recourse to; and the various important inventions, by which we communicate our feelings to a distance, such as writing and telegraphing, belong to this variety of language. For the deaf and dumb, our ordinary spoken language is translated into gestures, by which a conversation can be held, sufficient for all useful purposes; whilst the deaf, dumb, and blind are mainly

restricted to those gestures that are conveyed through their sense of touch.

Each acquired gesture is, like each acquired movement of the glottis, an evidence of the possession of intellect. The infant and the idiot have them not, because unable to appreciate their utility. The gestures resemble the spoken language in this and many other respects. The eye sees the gesture, to which the intellect attaches an idea as it does to the sound conveyed by the organ of hearing; and the will reproduces the gesture, in the same manner as it reproduces the sound heard. The lower extremities are, also, slightly concerned in the function of expression. They are agitated when impatient, and incessantly changing their position. The foot is stamped upon the ground in anger; and, like the upper extremity, is employed to convey to the object that has aroused the emotion the most unequivocal evidences of expression. Occasionally, the lower extremity is used as a part of conventional language, as when we tread upon the toes to arouse attention, or to convey insult. Nor are the internal organs foreign to the function of expression. The respiratory movements are affected,—the number of respirations being accelerated or retarded, or manifesting themselves under the different modifications of *sighing*, *yawning*, *laughing*, and *sobbing*. The heart, too, throbs at times to such an extent, that its action is perceptible externally; or, it may be retarded or hurried in its pulsations,—from a state of syncope or fainting to that of the most violent palpitation.

Lastly: the excretions, certain of them especially, are greatly implicated in many of these moral changes. That of the tears is a well-known and characteristic expression—of grief more especially, but occasionally of joy. The mind, however, may be so possessed by the emotion, that the ordinary power over the sphincter muscles may be more or less destroyed, and the contents of the rectum be spontaneously evacuated. The action of the stomach is, at times, inverted; and, at others, the peristaltic action is augmented. Who has not felt, whilst labouring under anxiety or dread, the constant desire not only to evacuate the fæces, but also the urinary secretion!

It is obvious, from this detail, that there is scarcely a function, which does not *express* some participation, when the mind is engaged in deep emotion; and that it would be vain to attempt to depict the various forms under which these manifestations may occur. What has been said will suffice to attract attention to the subject, which is not devoid of interest to the anthropologist.

In conclusion, we may refer to the question that has often been agitated, whether these rapid and violent movements, that characterize the expression of emotions, be *instinctive* or *natural* signs of the passion existing in the mind; or whether they be not voluntary muscular exertions, called for by the stress of the case, and constituting the means of resistance, or belonging simply to the outward manifestation of the inward emotion. The supporters of the latter view contend, that the various changes of facial expression or of gesture, which accompany the different mental emotions and indicate their character,

are, in all cases, the effect of habit, or are suddenly excited to accomplish some beneficial purpose. It is difficult, however, to regard the different concomitants of the passion as separate from it. Without them, the expression is incomplete; and, moreover, we observe the different gestures similarly developed in all the various races of mankind, when affected with the same mental contention. We must, consequently, regard the expressions as constituting a natural language, in which each has its appropriate sign; and this view is confirmed by the fact, that there are certain muscles of the face, which seem, in our existing state of knowledge, to be exclusively destined for expression; —those about the eyebrows and angles of the mouth for example. When the triangularis muscle and levator menti combine action, an expression is produced, which is peculiar to man; the angle of the mouth is drawn down, and the lip arched and elevated; hence the most contemptuous and proud expression.

A question of a different character has, however, been mixed up with this:—whether the infant be capable instinctively or naturally of comprehending the difference between the facial expressions of kindness or of frowns; some believing, that smiles are merely considered by it to be expressions of kindness, because accompanied by endearments,—and frowns to be proofs of displeasure, because followed by punishment. It is certain, however, that the infant interprets the countenance long before it can trace such sequences in its mind; but this does not remove the difficulty. The face of one, whom it has not been accustomed to see, will, at a very early period, impress it unfavourably, although the countenance may be unusually prepossessing; and the alteration of the ordinary expression of the material countenance may be attended with similar results. It is difficult, indeed, to comprehend how the child should be capable of discriminating between the smile and frown, when first presented to it. That organs may be associated in the expression of any encephalic act is intelligible; but that an act of judgment can be executed naturally or instinctively appears inexplicable. Sir Charles Bell,[1] who maintains the doctrine of the instinctive character of the expression of human passions, rejects the notion of instinctive expression in the face of the quadruped, contending that, even in the passion of rage, which is the most strongly marked of all the changes that occur in the features, are merely motions accessory to the great objects of opposition, resistance, and defence. "In carnivorous animals," he remarks, "the eyeball is terrible, and the retraction of the flesh of the lips indicates the most savage fury. But the first is merely the excited attention of the animal, and the other a preparatory exposure of the canine teeth." It appears to be a sufficient answer to this view, that no such expression is ever witnessed in other cases of excited attention, or in the simple exposure of the canine teeth, when the animal is devouring its food; unless, indeed, the repast be made during the existence of the passion.

On a former occasion, it was remarked, that the encephalon is exclusively concerned in the production of the different passions, and that

[1] Anat. of Expression, edit. cit.

the parts to which they are usually referred, attract our attention to them principally, in consequence of the sensation which accompanies them being there chiefly experienced. The same may be said of the different gestures that accompany the various emotions. They are dependent upon the influence exerted by the function of sensibility on the other functions. Gall,[1] in his system, has feebly attempted to show, that each gesture has a reference to the encephalic situation of the organ concerned in the production of the emotion of which it is a concomitant. The idea was suggested to him, he asserts, by the fact, observed by him a thousand times, that in fractures of the skull, the hand, (naturally we should think,) was carried mechanically to the seat of the fracture. He farther remarks, that the organs of the memory of words and of meditation are seated in the forehead; and that the hand is carried thither, whenever we are engaged in deep study;—that the organ of religious instinct corresponds to the vertex; and hence, in the act of prayer, all the gestures are directed towards that part of the body. Like every professed systematist, Gall is here pushing his principles *ad absurdum*. They are, indeed, controverted by facts. The hand is usually carried, not to the part of the encephalon in which any passion is effected, but to the part of the body in which its more prominent effects are perceptible,—as to the region of the stomach or heart; and frequently the gesture is referable to the determinate action, which must be regarded as a necessary effect of the passion.

Finally, *poetry* and *painting* belong properly to the varieties of expression; but they are topics that do not admit of elucidation by physiology.

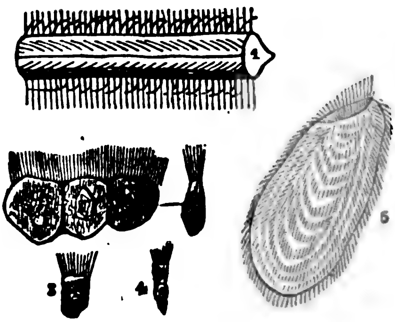
Here terminates the history of the animal functions, which have the common character of being periodically suspended by sleep. By many physiologists, this function has, therefore, been examined in this place; but as the nutritive and generative functions are, likewise, greatly influenced by sleep, we shall follow the example of M. Magendie,[2] and defer its study until those functions have been inquired into.

CILIARY MOTION.

Although not an animal function, it may be convenient to allude, in this place, to the phenomena of *vibratory* or *ciliary motion*, which, in recent times, have received the attention of observers. These terms have been employed to express the appearance produced by cilia,—a peculiar sort of moving bodies resembling small hairs, which are visible by the aid of the microscope, on parts that are covered with ciliary or vibratory epithelium.[3]

[1] Sur les Fonctions du Cerveau, v. 436, Paris, 1825.
[2] Précis Elémentaire, i. 366.
[3] See page 132; and, also, Sharpey, art. Cilia, Cyclop. of Anat. and Physiol., P. vi., p. 606, Lond., 1836; and Henle, Allgem. Anat., or Jourdan's French Translation, p. 251, Paris, 1843; and the excellent article Flimmerbewegung, by Valentin, in Wagner's Handwörterbuch der Physiologie, 3te Lieferung, s. 484, Braunschweig, 1842.

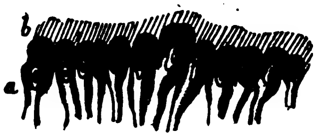
Fig. 208.



Cilia.

1. Portion of a bar of the gill of the *Mytilis edulis*, showing cilia at rest and in motion. 2. Ciliated epithelium particles from frog's mouth. 3. Ciliated epithelium particle from inner surface of human membrana tympani. 4. Ditto, ditto: from the human bronchial mucous membrane. 5. *Leucophrys patula*, a polygastric infusory animalcule; to show its surface covered with cilia, and the mouth surrounded by them. (Todd and Bowman.)

Fig. 209.



Vibratile or Ciliated Epithelium.

a. Nucleated cells, resting on their smaller extremities. *b*. Cilia.

This ciliary motion has been seen in different animals, on the external surface, in the alimentary canal, the respiratory system, the female generative organs; and in the cavities of the nervous system. It has not been observed, however, in the vagina; but may be traced from the lips of the os uteri through its cavity, and through the Fallopian tubes to their fimbriated extremities. In the upper classes of animals, it is not witnessed on the external surface except in the embryo. In most animals, a high magnifying power is necessary to perceive it. A small piece of mucous membrane, on which it exists, should be moistened with water, and covered with a plate of glass, by which the membrane is spread out, and its border rendered clearly visible. With the aid of a powerful microscope, an appearance of undulation is perceptible, and small bodies floating in the water may be seen, near the border of the membrane, to be driven along in a determinate direction. With a still higher magnifying power, the cilia themselves may sometimes be recognized, although seldom very distinctly, owing to the great rapidity of their motion. The influence of the motion on the fluids and small bodies in contact with the membrane may be well exhibited by strewing a fine powder on the surface; as the motion of the cilia has a uniform direction, it gives rise to currents over the surface of the membrane.

An easy mode of observing the phenomenon is to scrape with a knife a few scales of epithelium from the back of the throat of a living frog. If these be moistened with water or serum, they will continue to exhibit the motion of the adherent cilia for a very considerable time, if the epithelium be only kept moistened. On one occasion, Messrs. Todd and Bowman observed a piece of epithelium prepared in this manner exhibit motion for seventeen hours; and they thought it would probably have done so for a longer time had not the moisture around it evaporated. In the turtle, after death by decapitation, MM. Purkinje and Valentin found it lasted in the mouth nine days; in the trachea and lung, thirteen days; and in the œsophagus, nineteen days.[1]

[1] Physiological Anatomy and Physiology of Man, by Messrs. Todd and Bowman, p. 62, Lond., 1843.

According to M. Donné,[1] cilia are seen only on the "true mucous membranes" of his division,[2] or those that secrete an alkaline mucus. They are never met with on the acid membranes, which are analogous to the skin, and simple reflections of the cutaneous envelope. Hence, they are not found in the mouth or vagina, but in the nasal and bronchial mucous membrane.

The organs of ciliary motion are delicate transparent filaments, varying in length, according to Purkinje and Valentin, from $\frac{1}{12807}$ to $\frac{1}{1016}$ of an inch, and are generally thicker at the base than at the free extremity. Their motion continues after death as long as the tissues retain their contractility, and often much longer. Müller[3] thus sums up the present state of our knowledge in regard to the phenomenon: That the ciliary motion of the mucous membranes is due to the action of some unknown contractile tissue, which lies either in the substance of the cilia or at their base,—that this tissue resembles in contractility the muscular and other contractile tissues of animals;—that its properties so far agree with those of the muscular tissues—at all events with those of the involuntary muscles of the heart, and the vibratory laminæ of the lower crustacea;—that the motions, which it produces, continue without ceasing with an equable rhythm;—that its properties agree also with those of the muscular tissue of the heart in its motions, continuing long after the separation of the part from the rest of the animal body;—that this tissue differs essentially, however, from muscle, in the circumstance of its motions not being arrested by the local application of narcotics; and lastly, that the ciliary motion presents itself under conditions where it is not probable that a complicated organization exists,—namely, in the undeveloped embryos of polypiferous animals.

M. Donné[4] regards the cilia as animalcules; resembling in many respects the spermatozoids. They certainly resemble each other; but there is no sufficient reason to believe either of them animalcular.

The production of currents by the ciliary motion is not easy of explanation. Purkinje and Valentin ascribe them to the return of the cilia from the bent to the erect state, which gives an impulse to the fluid. The direction in which the cilia act is most commonly towards the outlet of the canal on which they are placed; but, as Mr. Paget[5] has remarked, their special purpose is in many instances—for example, in the ventricles of the brain—as uncertain as the power by which they act.

We shall have to refer to ciliary motion under other heads.

[1] Cours de Microscopie, p. 170, Paris, 1844.
[2] See Secretion of Mucus in vol. ii. of this work.
[3] Elements of Physiology, by Baly, P. iv. p. 866, Lond., 1838.
[4] Op. cit., p. 176.
[5] Brit. and For. Med. Review, July, 1842, p. 264.

BOOK II.

NUTRITIVE FUNCTIONS.

THE human body, from the moment of its formation to the cessation of existence, is undergoing constant decay and renovation—decomposition and composition:—so that at no two periods can it be said to have exactly the same constituents. The class of functions about to engage attention, embraces those that are concerned in effecting such changes. They are seven in number;—*digestion*, by which the food, received into the stomach, undergoes such conversion as fits it for the separation of its nutritious and excrementitious portions; *absorption*, by which this nutritious portion, as well as other matters, is conveyed into the mass of blood; *respiration*, by which the products of absorption and venous blood are converted into arterial blood; *circulation*, by which the vital fluid is distributed to every part of the system; *nutrition*, by which the intimate changes of composition and decomposition are accomplished; *calorification*, by which the system is enabled to resist the effects of greatly elevated or depressed atmospheric temperature, and to exist in the burning regions within the tropics, or amidst the arctic snows; and *secretion*, by which various fluids and solids are separated from the blood;—some to serve useful purposes in the animal economy; others to be rejected from the body.

CHAPTER I.

OF DIGESTION.

THE food, necessary for animal nutrition, is rarely found in such a condition as to be adapted for absorption. It has, therefore, to be subjected to various actions in the digestive organs; the object of which is to enable the nutritive matter to be separated from it. These actions constitute the function of digestion; in the investigation of which we shall commence with a brief description of the organs concerned in it. These are numerous, and of a somewhat complicated nature.

1. ANATOMY OF THE DIGESTIVE ORGANS.

The human digestive organs consist of a long canal, varying considerably in its dimensions in different parts, and communicating externally by two outlets,—the *mouth* and *anus*. It is usually divided into four chief portions—the *mouth*, *pharynx*, *œsophagus*, *stomach*, and *intestines*. These we shall describe in succession.

1. The *mouth* is the first cavity of the digestive tube, and that into which the food is immediately received, and subjected to the action of the organs of mastication and insalivation. Above and below, it is circumscribed by the jaws, and laterally by the cheeks;—anteriorly by the lips and their aperture, constituting the mouth proper; and, posteriorly, it communicates with the next portion of the tube,—the pharynx. It is invested by a mucous exhalant membrane, which is largely supplied with follicles; and into it the ducts from the different salivary glands pour their secretion.

Fig. 210.

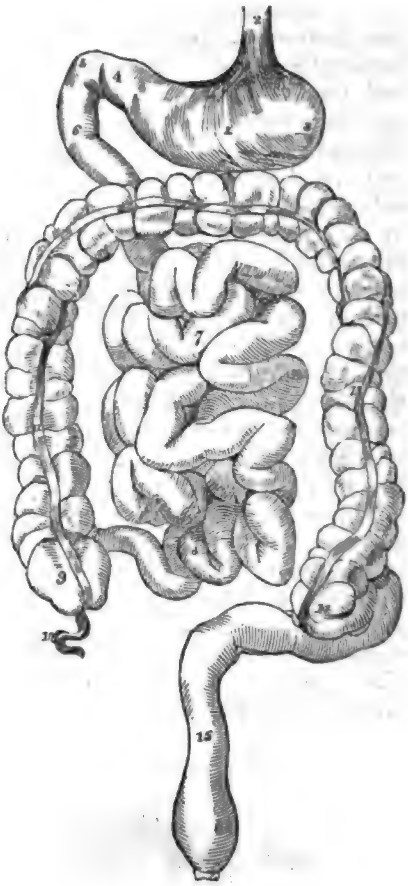


Diagram of the Stomach and Intestines to show their course.

1. Stomach. 2. Œsophagus. 3. Left, and 4. Right end of stomach. 5, 6. Duodenum. 7. Convolutions of jejunum. 8. Those of ileum. 9. Cæcum. 10. Vermiform appendix. 11. Ascending; 12. Transverse; and 13. Descending colon. 14. Commencement of sigmoid flexure. 15. Rectum.

In all animals furnished with distinct digestive organs, means exist for comminuting the food, and enabling the stomach to act with greater facility upon it. These consist, for the most part, as in man, of the jaws, the teeth fixed into the jaws, and muscles by which the jaws are moved.

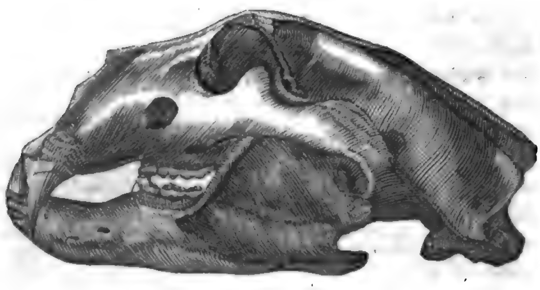
The *jaws* chiefly determine the shape and dimensions of the mouth; the *upper* forming an essential part of the face, and moving only with the head; the *lower*, on the contrary, possessing great mobility. Each of the jaws has a prominent edge, forming a semicircle, in which the teeth are implanted. This edge is called the *alveolar arch*.

The *teeth* are small organs, of a density superior to bone; and covered externally by a hard substance called *enamel*. By many, they have been regarded as bone; but they differ from it in many essential respects, although they resemble it in hardness and chemical composition. At another opportunity we shall inquire into their origin, structure, and developement. We may merely remark, at present, that by many they are looked upon as analogous to the corneous substances, which develope themselves in the tissue of the skin. De Blainville assimilates them to the hair; and believes, that they are primarily developed in the substance of the membrane lining the mouth; and that their enclosure in the substance of the alveolar arches of the jaws occurs subsequently.

The number of the teeth is sixteen in each jaw. These are divided into classes, according to their shape and use. There are, in each jaw, four *incisores;* two *cuspidati* or *canine* teeth; four *bicuspidati;* and six *molares* or *grinders.* Each tooth has three parts:—the *crown, neck,* and *fang* or *root;*—the first being the part above the gum; the second that embraced by the gum; and the third, the part contained in the *alveolus* or socket. The crown varies in the different classes. In the incisors, it is wedge-shaped; in the canine, conical; and in the molar, cubical. In all, it is of extreme hardness, but in time wears away by the constant friction to which it is exposed. The incisor and canine teeth have only one root; the molares of the lower jaw, two; and the upper, three. In all cases, they are of a conical shape, the base of the cone corresponding to the corona, and the apex to the bottom of the alveolus. The alveolar margin of the jaws is covered by a thick, fibrous, resisting substance, called *gum.* It surrounds accurately the inferior part of the crown of the tooth, adheres to it strongly, and thus adds to the solidity of the junction of the teeth with the jaws. It is capable of sustaining considerable pressure without inconvenience.—But we shall have to return to the subject of the teeth hereafter.

The articulation of the lower jaw is of such a nature as to admit of depression and elevation; of horizontal motion forwards, backwards, and laterally; and of a semi-rotation upon one of its condyles. The muscles that move it may be thrown into two classes:—*elevators* and *depressors.* These, by a combination of their contraction, can produce every intermediate movement between elevation and depression. The raisers or levator muscles of the jaw extend from the cranium and upper jaw to the lower. They are four in number on each side,—the *temporal,* and *masseter,* which are entirely concerned in the function; the *external pterygoid,* which, whilst it raises the jaw, carries it at the same time forward, and to one side; and the *internal pterygoid,* which, according as it unites its action with the temporal or with the external pterygoid, is an elevator of the jaw or a lateral motor. The depressors may be divided into immediate and mediate, according as they are, or are not, attached to the lower jaw itself. There are only three of the former class: 1, the *digastricus,* the anterior fasciculus of which, or that which passes from the os hyoides to the lower jaw, depresses the latter; 2, the *genio-hyoideus;* and 3, the *mylo-hyoideus,* all of which concur in the formation of the floor of the mouth. The indirect or mediate depressors are all those, that are situate between the trunk and the lower jaw, without being directly attached to the latter;—as the *thyro-hyoideus,*

Fig. 211



Skull of the Polar Bear.

the *sterno-thyroideus*, and the *omo-hyoideus;* the names of which indicate their origin and insertion. These, in the aggregate, form a muscular chain, which, when it makes the trunk its fixed point, depresses the lower jaw. The arrangement of the elevators and depressors is such, that the former predominate over the latter; and hence during sleep the jaws continue applied to each other, and the mouth is consequently closed.

The human organs of mastication hold an intermediate place between those of the carnivorous and herbivorous animal. In the carnivorous animal, which has to seize hold of, and retain its prey between its teeth, the jaws have considerable strength; and the movement of elevation is all that is practicable; or, at least, that can be effected to any extent. This is dependent upon organization. The condyle is broader from side to side, which prevents motion in that direction: the glenoid cavity is very deep, so that the head of the jaw-bone cannot pass out of it; and it is, moreover, fixed in its place by two eminences before and behind. The muscular apparatus is also so arranged as to admit of energetic action on the part of the muscles that raise the jaw; but of scarcely any in a horizontal direction. The deep impressions in the regions of the temporal and masseter muscles indicate the large size of these muscles in the purely carnivorous animal; whilst the pterygoid muscles are extremely small. The teeth, too, are characteristic; the molars being comparatively small, at the same time that they are much more pointed. On the other hand, the cuspidati are remarkably large, and the incisors, in general, acuminated.

Fig. 212.

Skull of the Cow.

The herbivorous animal has an arrangement the reverse of this. The condyle or head of the lower jaw is rounded; and can, therefore, be moved in all directions; and as easily horizontally as up and down. The glenoid cavity is shallow, and yields the same facilities. The articulation, which is very close in the carnivorous animal, is here quite loose. The levator muscles are much more feeble; the temporal fossa is less deep; the zygomatic arch less convex; and the zygomatic fossa less extensive. On the other hand, the pterygoid fossa is ample and the muscles of the same name are largely developed. The molares are large and broad; and their magnitude is so great as to require, that the jaw should be much elongated in order to make room for them.

The joint of the lower jaw has, in man, solidity enough for the jaws to exert considerable pressure with impunity, and laxity enough that the lower jaw may execute horizontal movements. The action of the leva-

tor muscles is the most extensive; but the lateral or grinding motion is practicable to the necessary extent; and the muscles of both kinds have a medium degree of developement. The teeth, likewise, partake of the characteristics of those of the carnivorous and herbivorous animals;—twelve—the canine teeth and lesser molares—corresponding to those of the carnivorous; and twenty—the incisors and larger molares—to those of the herbivorous.

The tongue must be regarded as an organ of mastication. It rests horizontally on the floor of the mouth; is free above, anteriorly; and, to a certain extent, beneath and at the sides. Behind, it is united to the epiglottis by three folds of the mucous membrane of the mouth; and is supported at its base by the os hyoides, with which it participates in its movements. The tongue, as the organ of taste and articulation, has been described already (p. 145). We have only, therefore, to describe the os hyoides and its attachment to that bone. The hyoid bone has, as its name imports, the shape of the Greek letter υ, the convex part being before. (Fig. 194.) It is situate between the tongue and larynx: and is divided into *body* or *central part;* and into branches, one extremity of which is united to the body by an intermediate cartilage, that admits of slight motion; whilst the other is free, and is called *greater cornu.* Above the point, at which the branch is articulated with the body, is an apophysis or process, called *lesser cornu.* The os hyoides is united to the neighbouring parts by fibrous organs, and muscles. The former are;—*above*, the *stylo-hyoid ligament*, which extends from the lesser cornu of the bone to the styloid process of the temporal bone; *below*, a fibrous membrane, called *thyro-hyoid*, passing between the body of the bone and the thyroid cartilage; and two ligaments, extending from the greater cornu of the hyoid bone to the thyroid cartilage, called *thyro-hyoid.* Of the muscles; some are above the hyoid bone, and raise it;—viz., the *genio-* and *mylo-hyoideus*, already referred to; the *stylo-hyoid*, and some fibres of the *middle constrictor of the pharynx.* Others are below, and depress it. They are the *sterno-thyro-hyoideus*, *omo-hyoideus* and *sterno-thyroideus.* The base of the tongue is attached to the body of the bone by a ligamentous tissue, and by the fibres of the *hyoglossus* muscle.

Among the collateral organs of mastication are those which secrete the saliva, and the various fluids which are poured out into the mouth,—constituting together what has been termed the *apparatus of insalivation.* These fluids proceed from different sources. The mucous membrane of the mouth, like other mucous membranes, exhales a serous or albuminous fluid, besides a mucous fluid secreted by the numerous follicles contained in its substance. Four glands likewise exist on each side, destined to secrete the *saliva*, which is poured into the mouth by distinct excretory ducts. They are the *parotid*, *submaxillary*, *sublingual*, and *intra-lingual* or *lingual.* The first is situate between the ear and the jaw; and its excretory duct opens into the mouth opposite the second small molaris of the upper jaw. By pressing upon this part of the cheek, the saliva can be made to issue into the mouth, in perceptibly increased quantity. The submaxillary gland is situate beneath the base of the jaw; and its excretory duct opens into

Fig. 213.

Sälivary Glands in situ.

1. Parotid gland in situ, extending from the zygoma above, to the angle of the jaw below. 2. Duct of Steno. 3. Submaxillary gland. 4. Its duct. 5. Sublingual gland.

the mouth at the side of the frænum linguæ. The sublingual gland is situate under the tongue, and its excretory ducts open at the sides of that organ, and the intra-lingual or lingual is seated at the inferior surface of the tongue, where the mucous membrane forms a fringed fold. These glands are constantly pouring saliva into the mouth; and it has been presumed, that the fluids secreted by them may differ from each other in physical and chemical characters. Such, at least, has been the view of some as regards the sublingual, the texture of which more nearly resembles that of the compound follicles than of glands; but the circumstance has not been proved by any direct experiment. The saliva, as met with, is a compound of every secretion poured into the mouth; and it is this fluid which has been chiefly subjected to analysis. The secretion of the saliva, and its various properties, will be considered, however, hereafter.

The two apertures of the mouth are the *labial* and *pharyngeal.* The former, as its name imports, is formed by the lips, which consist externally of a layer of skin; are lined internally by a mucous membrane; and, in their substance, contain numerous muscles, already described under the head of Gestures. These muscles may be separated into *constrictors* and *dilators;* the *orbicularis oris* being the only one of the first class, and the antagonist to the others, which are eight in number, on each side—*levator labii superioris alæque nasi, levator labii superioris proprius, levator anguli oris, zygomaticus major, zygomaticus minor, buccinator, triangularis,* and *quadratus menti.* (Fig. 201.) To the last two muscles are added some fibres of the *platysma myoides.*

The *pharyngeal opening* is smaller than the labial, and of a quadrilateral shape. It is bounded above by the *velum palati* or *pendulous veil of the palate;* below, by the base of the tongue; and laterally, by two muscles, which form the *pillars of the fauces.* The pendulous veil is a musculo-membranous extension, constituting a kind of valve, attached to the posterior margin of the bony palate, by which all communication between the mouth and pharynx, or between the pharynx and nose can be prevented. (Fig. 214.) To produce the first of these effects, it becomes vertical; to produce the latter, horizontal. At its inferior and free margin, it has a nipple-like shape, and bears the name

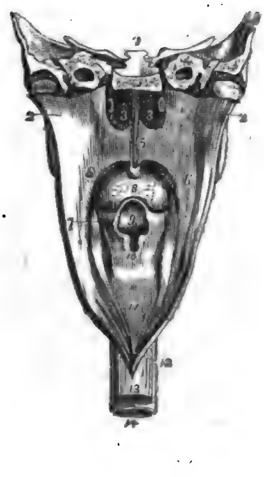
Fig. 214.

Cavity of the Mouth, as shown by dividing the Angles and turning off the Lips.

1. Upper lip, turned up. 2. Its frænum. 3. Lower lip, turned down. 4. Its frænum. 5. Internal surface of cheeks. 6. Opening of duct of Steno. 7. Roof of mouth. 8. Anterior portion of lateral half arches. 9. Posterior portion of lateral half arches. 10. Velum pendulum palati. 11. Tonsils. 12. Tongue.

of *uvula*. It is composed of two mucous membranes, and of muscles. One of the membranes,—that forming its anterior surface—is a prolongation of the membrane lining the mouth, and contains numerous follicles; the other, forming its posterior surface, is an extension of the mucous membrane lining the nose, and is redder, and less provided with follicles than the other. The muscles that constitute the body of the velum palati are — the *circumflexus palati* or *spheno-salpingo-staphylinus* of Chaussier; the *levator palati* or *petro-salpingo-staphylinus;* and the *azygos uvulæ* or *palato-staphylinus*. The velum is moved by eight mus-

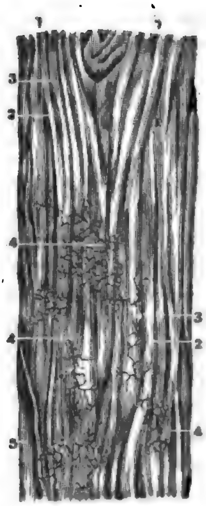
Fig. 215.



Pharynx seen from behind.

1. A section carried transversely through base of skull. 2, 2. Walls of pharynx drawn to each side. 3, 3. Posterior nares, separated by vomer. 4. Extremity of Eustachian tube of one side. 5. Soft palate. 6. Posterior pillar of soft palate. 7. Its anterior pillar; the tonsil seen situate in the niche between the two pillars. 8. Root of tongue, partly concealed by uvula. 9. Epiglottis, overhanging (10) opening of glottis. 11. Posterior part of larynx. 12. Opening into œsophagus. 13. External surface of œsophagus. 14. Trachea.

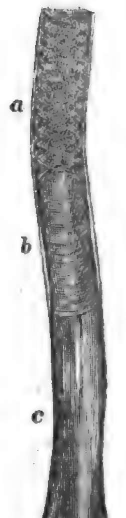
Fig. 216.



Longitudinal Section of Œsophagus, near the Pharynx, seen on its inside.

1, 1. Superior part near pharynx. 2, 2. Longitudinal folds of its mucous membrane. 3, 3. Prominences formed by its muciparous glands. 4, 4. Capillary bloodvessels. 5. Shows the muscular coat after the mucous coat has been turned off.

Fig. 217.



Section of the Œsophagus.

a, *b*. Internal circular fibres. *c*. External longitudinal fibres.

cles. The two *internal pterygoids* raise it; the two *external pterygoids* stretch it transversely; the two *palato-pharyngei* or *pharyngo-staphylini*, and the two *constrictores isthmi faucium* or *glosso-staphylini* carry it downwards. The last four muscles form the pillars of the fauces;—the first two the posterior pillars; and the last two the anterior; between which are situate the *tonsil glands* or *amygdalæ*, which are not really glandular, but composed of a congeries of mucous follicles.

2. The *pharynx* and *œsophagus* constitute a muscular canal, which forms the medium of communication between the mouth and stomach, and conveys the food from the former of these cavities to the latter.

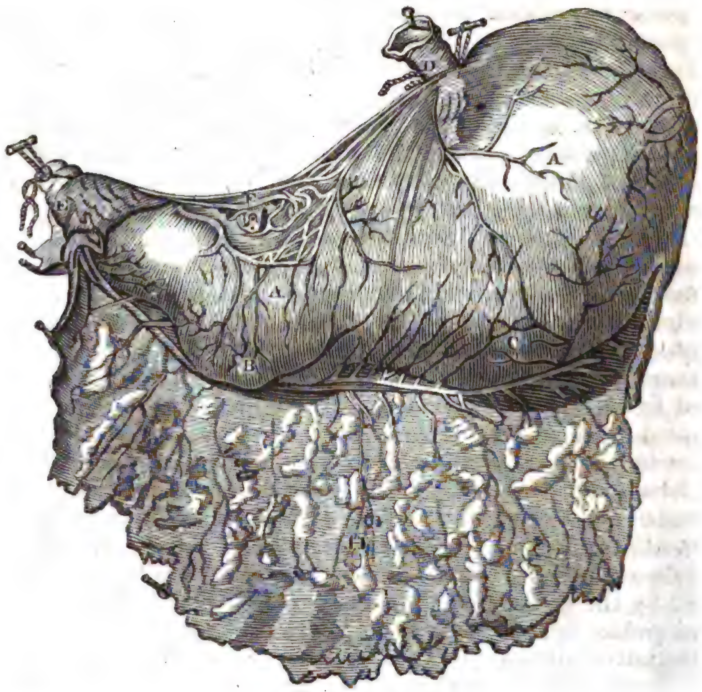
The *pharynx* has the shape of an irregular funnel,—the larger opening of the funnel looking towards the mouth and nose; the under and smaller end terminating in the œsophagus. Into its upper part, the nasal fossæ, Eustachian tubes, mouth, larynx, and œsophagus open. It is inservient to useful purposes in the production of voice, respiration, audition, and digestion; and extends from the basilary process of the occipital bone, to which it is attached, as far as the middle part of the neck. Its transverse dimensions are determined by the os hyoides, larynx, and pterygo-maxillary apparatus, to which it is attached. It is lined by a mucous membrane, less red than that which lines the mouth, but more so than that of the œsophagus, and the rest of the digestive tube; and it is remarkable for the developement of its veins, which form a very distinct network. Around this is the muscular layer, the circular fibres of which are often divided into three muscles—*superior*, *middle*, and *inferior constrictors*. The longitudinal fibres form part of the *stylo-pharyngei* and *palato-pharyngei* muscles. The pharynx is raised by the action of the last two muscles, as well as by all those that are situate between the lower jaw and os hyoides, which cannot raise the latter without, at the same time, raising the larynx and pharynx. These muscles are:—*mylo-hyoideus*, *genio-hyoideus*, and the anterior belly of the *digastricus*.

The *œsophagus* is a continuation of the pharynx; and extends to the stomach, where it terminates. Its shape is cylindrical, and it is connected with the surrounding parts by loose and extensible areolar tissue, which yields readily to its movements. On entering the abdomen, it passes between the pillars of the diaphragm, with which it is intimately united. The mucous membrane lining it is pale, thin, and smooth; forming longitudinal folds, well adapted for favouring the dilatation of the canal. Above, it is confounded with that of the pharynx; but below, it forms several digitations, terminated by a fringed extremity, which is free in the cavity of the stomach. It is well supplied with mucous follicles. The muscular coat is thick; its texture is denser than that of the pharynx,—and cannot, like it, be separated into distinct muscles, but consists of circular and longitudinal fibres, the former of which are more internal, and very numerous, the latter external and less numerous. Fig. 217 exhibits the situation and arrangement of the two sets of fibres.

3. The *stomach* is situate in the cavity of the abdomen, and is the most dilated portion of the digestive tube. It occupies the epigastric region, and a part of the left hypochondre. Its shape has been com-

pared, not inappropriately, to that of the bag of a bag-pipe. It is capable of holding, in the adult male, when moderately distended, about three pints. The left half of the organ has always much greater

Fig. 218.



Stomach seen Externally.

A, A. Anterior surface. B. Enlargement at lower part. D. Cardiac orifice. E. Commencement of duodenum. F and C. Coronary vessels. H. Omentum.

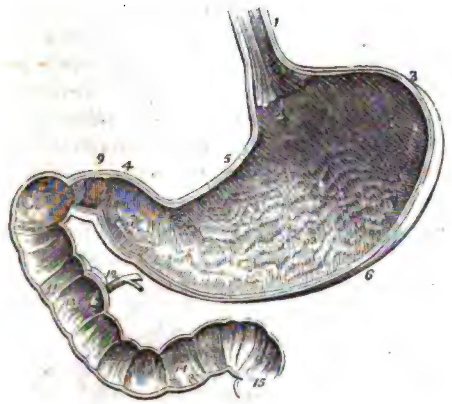
dimensions than the right. The former has been called the *splenic portion*, because it rests upon the spleen; the latter the *pyloric portion*, because it corresponds to the pylorus. The inferior border of the *stomach*, which is convex, is termed the *great curvature* or *arch;* the superior border, the *lesser curvature* or *arch*. The two orifices are the *œsophageal*, *cardiac*, or *upper orifice*, formed by the termination of the œsophagus; and the *intestinal*, *pyloric* or *inferior orifice*, which communicates with the small intestine.

The three coats that constitute the parietes of the stomach, are arranged in a manner the most favourable for permitting variation in the size of the organ. The outermost or *peritoneal coat* consists of two laminæ, which adhere but slightly to the organ, and extend beyond it, where they form the *epiploons* or *omenta*, the extent of which is in an inverse ratio to the degree of distension of the stomach. The *omentum majus* or *gastro-colic epiploon* is the part that hangs down from the stomach in Fig. 218.

The mucous or lining membrane is of a whitish, marbled, red appear-

ance, having a number of irregular folds, situate especially along the inferior and superior margins of the organ. These folds are evident, also, at the splenic extremity; and are more numerous and marked, the more the stomach is contracted. They are radiated towards the cardiac,—longitudinal towards the pyloric, orifice. This membrane, like every other of the kind, exhales an albuminous fluid from a multitude

Fig. 219.



Vertical and Longitudinal Section of Stomach and Duodenum.

1. Œsophagus; upon its internal surface, the plicated arrangement of cuticular epithelium shown. 2. Cardiac orifice of stomach, around which the fringed border of cuticular epithelium is seen. 3. Great end of stomach. 4. Its lesser or pyloric end. 5. Lesser curve. 6. Greater curve. 7. Dilatation at lesser end of stomach which received from Willis the name of *antrum of pylorus*. This may be regarded as the rudiment of a second stomach. 8. Rugæ of the stomach formed by mucous membrane: their longitudinal direction is shown. 9. Pylorus. 10. Oblique portion of duodenum. 11. Descending portion. 12. Pancreatic duct, and ductus communis choledochus, close to their termination. 13. Papilla upon which ducts open. 14. Transverse portion of duodenum. 15. Commencement of jejunum. In interior of duodenum and jejunum, the valvulæ conniventes are seen. (Wilson.)

Fig. 220.

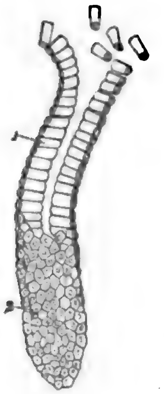
Section of a piece of Stomach not far from Pylorus.

1. Magnified about three diameters. 2. A few of the glands with their racemiform ends distended with fluid, magnified about 20 diameters. (Wagner.)

of delicate villi, which are as perceptible in the stomach as in any part of the digestive tube. It contains, likewise, many follicles, which are especially abundant in the pyloric portion. (Fig. 220.) Several, also, exist in the vicinity of the cardiac orifice, but in the rest of the membrane they are few in number. When examined with a magnifying glass, the internal or free surface presents a peculiar honeycomb appearance, produced by shallow polygonal depressions or cells as represented in the marginal figure. (Fig. 223.) The diameter of these cells varies from $\frac{1}{200}$th to $\frac{1}{300}$th of an inch; but, near the pylorus, it is as much as $\frac{1}{100}$th of an inch. In the bottom of the cells, minute openings are visible, which are the orifices of perpendicular glands embedded, side by side, in bundles in the substance of the mucous membrane, and composing nearly the whole structure.[1] These tubular follicles vary in

[1] Dr. Sprott Boyd, Edinb. Med. and Surg. Journal, vol. xlvi.

Fig. 221.



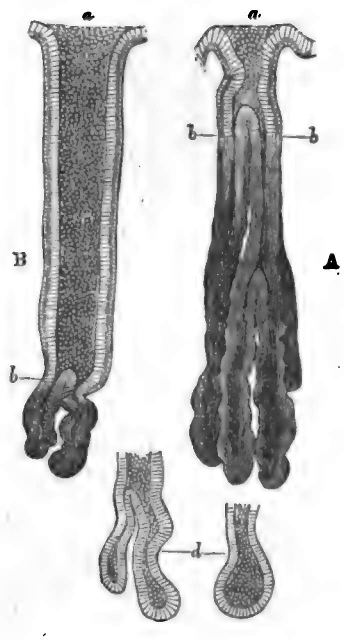
Tubular Follicle of Pig's Stomach. (After Wasmann.)

length from one-fourth of a line to nearly a line. They are longer and more closely set towards the pylorus than elsewhere, their length being equal to the thickness of the mucous membrane of the stomach, which varies.

The office of these tubular follicles, it has been thought, is to secrete the gastric fluid, during digestion; for in the intervals they are at rest. They are formed by inflections of basement membrane, with cylindrical epithelium resting upon it. One of them is represented in the marginal figure, which exhibits the nucleated cells at the bottom of the follicle; becoming more and more developed as they approach the free surface. These cells prepare the gastric fluid, and ultimately burst and discharge it to become mixed with the aliment in the stomach.

Besides these glands or follicles, small opaque—white sacculi, resembling Peyer's glands, are met with, which are filled with minute cells and granules. They are situate chiefly along the lesser curvature of the stomach

Fig. 222.

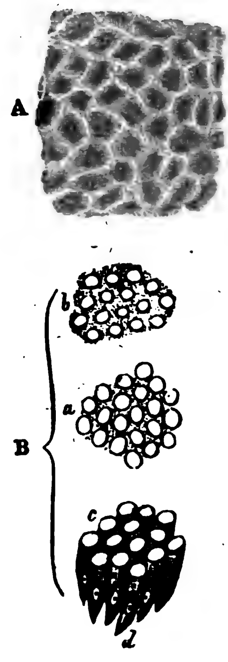


Vertical Section of a Stomach Cell, with its Tubes.

A. In the middle region. B. In the pyloric region. *a*, *a*. Orifices of the cells on the inner surface of the stomach. *b*, *b*. Different depths at which the columnar epithelium is exchanged for glandular. *c*. Pyloric tube, or prolonged stomach cell. *d*. Pyloric tubes, terminating variously, and lined to their extremities with sub-columnar epithelium.

From the dog, after twelve hours' fasting.—Magnified 200 diameters.

Fig. 223.



Mucous Membrane of the Stomach.

A. Inner surface of the stomach, showing the cells after the mucus has been washed out.—Magnified 25 diameters.

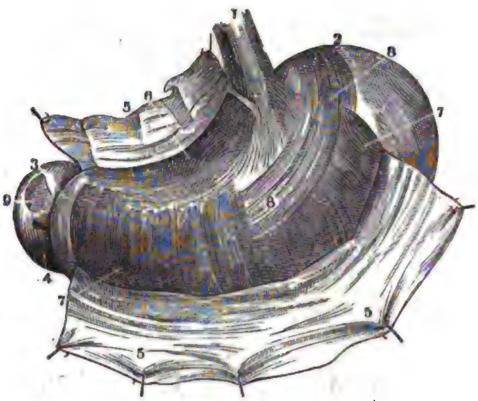
B. Columnar epithelium of the inner surface and cells of the stomach. *a*. Free ends of the epithelial particles, seen on looking down upon the membrane. *b*. Nuclei visible at a deeper level. *c*. The free ends seen obliquely. *d*. Deep or attached ends of the same. The oval nuclei are seen near the deeper ends.

From the dog.—Magnified 300 diameters.

beneath the lining membrane; are probably concerned in the separation of some secretion from the blood, and when filled burst, like other secreting cells, and discharge their contents into the stomach.[1]

The *pylorus*, or the part at which the stomach terminates in the small intestine, is marked, externally, by a manifest narrowness, as at 9, Fig. 219. Internally, the mucous membrane forms a circular fold, which has been called *valve of the pylorus*, between the two laminæ of which, a dense, fibrous tissue exists. This has been called by some authors, *pyloric muscle*.

Fig. 224.



Front View of Stomach, distended by flatus, with Peritoneal Coat turned off.

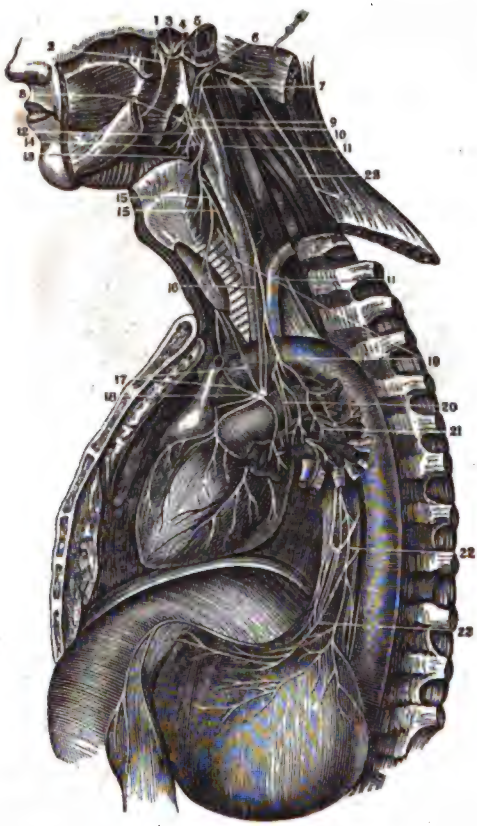
1. Anterior face of œsophagus. 2. Cul-de-sac, or greater extremity. 3. Lesser or pyloric extremity. 4. Duodenum. 5, 5. A portion of the peritoneal coat turned back. 6. A portion of the longitudinal fibres of the muscular coat. 7. Circular fibres of the muscular coat. 8. Oblique muscular fibres, or muscle of Gavard. 9. A portion of the muscular coat of the duodenum, where its peritoneal coat has been removed.

The *muscular coat*, which is exterior to the mucous coat,—as in the parts of the digestive tube already described,—consists of several laminæ of fibres, less distinct than those of the œsophagus; or rather more irregularly distributed. The most common opinion is, that there are three laminæ:—an external, *longitudinal* series; a middle *transverse* or *circular* stratum; and an inner stratum with fibres running *obliquely*. Both circular and longitudinal fibres are separated from each other, especially in the splenic portion,—the separation augmenting or diminishing with the varying size of the stomach.

The blood-vessels and nerves of the stomach are more numerous than those of any other organ of the body. The arteries are disposed along the curvatures. On the lesser curvatures are,—coronaria ventriculi, and the pyloric branch of the hepatic artery; on the great curvature, the right gastro-epiploic, which is a branch of the hepatic; and the left gastro-epiploic,—a branch of the splenic. The splenic artery, too, furnishes numerous branches to the left *cul-de-sac* behind. These are called *vasa brevia* or *gastro-splenic*. The nerves of the stomach are of two kinds. Some proceed from the great sympathetic, from the cœliac plexus, and accompany the arteries through all their ramifications. Others are furnished by the pneumogastric or eighth pair; the two nerves of which surround the cardiac orifice like a ring. The number of the nerves, and the variety of sources whence they are derived, explain the great sympathetic influence exerted upon the stomach by affections of other parts of the system. It sympathises, indeed, with

[1] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 167, Philad., 1849.

Fig. 225.



Distribution of the Glosso-Pharyngeal, Pneumogastric and Spinal Accessory Nerves, or the Eighth Pair.

1. The inferior maxillary nerve. 2. The gustatory nerve. 3. The chorda tympani. 4. The auricular nerve. 5. Its communication with the portio dura. 6. The facial nerve coming out of the stylo-mastoid foramen. 7. The glosso-pharyngeal nerve. 8. Branches to the stylo-pharyngeus muscle. 9. The pharyngeal branch of the pneumogastric nerve descending to form the pharyngeal plexus. 10. Branches of the glosso-pharyngeal to the pharyngeal plexus. 11. The pneumogastric nerve. 12. The pharyngeal plexus. 13. The superior laryngeal branch. 14. Branches to the pharyngeal plexus. 15, 15. Communication of the superior and inferior laryngeal nerves. 16. Cardiac branches. 17. Cardiac branches from the right pneumogastric nerve. 18. The left cardiac ganglion and plexus. 19. The recurrent or inferior laryngeal nerve. 20. Branches sent from the curve of the recurrent nerve to the pulmonary plexus. 21. The anterior pulmonary plexus. 22, 22. The œsophageal plexus.

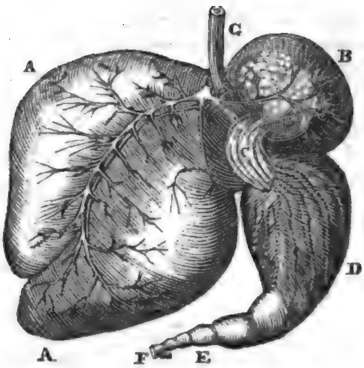
every protracted morbid change in the individual organs; and hence was termed, by Mr. Hunter, the *centre of sympathies.*

Like the teeth, the human stomach holds a medium space between that of the carnivorous and herbivorous animal. As the former makes use of aliment, which is more readily assimilated to its own nature, and more nutritious, it is not necessary that it should take food in such large quantities as the latter, or that this should remain so long in the stomach. On this account, the organ is generally of much smaller size. On the other hand, as the herbivora subsist solely upon grass, which contains but a small quantity of nutritious matter, and that not easy of assimilation, it is important that the quantity taken in should be ample; that it should remain for some time in the organ, subjected to the action of its secretions; and, in the ruminant class, be returned into the mouth, to undergo fresh mastication.

In this class, the stomach is of prodigious extent. In the ox, which we may take as an example of the general structure of the organ, it consists of four separate compartments. The first stomach, A A, Fig. 226, *ventriculus* or *paunch*, is much the largest. Externally, it has two sacs or appendices; and, internally, is slightly divided into four compartments. The second stomach is the *reticulum*, *bonnet* or *honey-comb bag*, B, which appears to be a globular appendix to the paunch. It is situate to the right of the œsophagus, G, and has usually a thicker muscular coat than the paunch. Its inner surface is arranged in irregular pentagonal

cells, and is covered with fine papillæ. The third stomach, C, is the smallest, and is called *omasum* or *manyplies*. It is of a globular shape, and has a thinner muscular coat than the former. It consists of numerous broad laminæ, sent off from the internal coat, running in a longitudinal direction, alternately varying in breadth, and covered with a small granular papillæ. The fourth stomach, D, is the *abomasum*, *ventriculus intestinalis* or *caillette*. It has a pyriform shape, and is next in size to the paunch. It has large longitudinal rugæ, covered with villi. The muscular coat is still thinner than that of the former. This stomach is the only one that resembles the human organ; and, in the young of the ruminant animal, with the milk curdled in it, forms the *runnet* or *rennet*. The property of curdling milk is, however, possessed by all digestive stomachs. The inner surface of the three first stomachs is covered with cuticle; whilst that of the fourth is lined by a true mucous or secreting membrane. There is in the interior arrangement of the stomachs of the ruminant animal a singular provision by which the food can be either received into the first and second stomachs, or be carried on into the third, if its character be such as to be fitted at first for the action of the omasum.

Fig. 226.

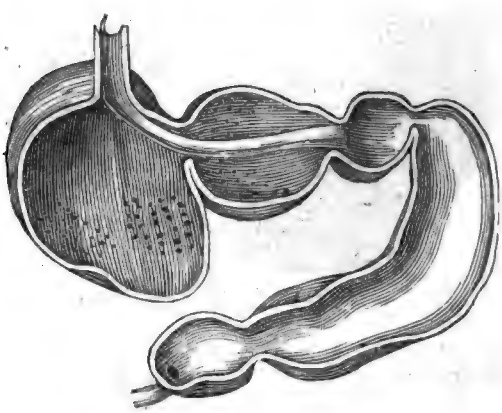


Stomach of the Ox.

A, A. Paunch. B. Reticulum. C. Omasum. D. Abomasum. E. Pylorus. F. Duodenum. G. Œsophagus.

From the œsophagus, in Fig. 227, a gutter passes into the second and third stomachs. The third leads into the fourth by a narrow opening, and the fourth terminates in the duodenum, which has a pylorus as its origin. When the animal eats solid food, it is, after slight mastication, passed into the paunch, and thence, by small portions, into the second stomach. When this has become mixed with fluid, and kept for some time at a moderately high temperature, a morsel is thrown back with velocity from the stomach into the mouth, where it is "ruminated," and then swallowed and passed on into the third stomach,—the groove or gutter being now so contracted as to form a channel for its

Fig. 227.

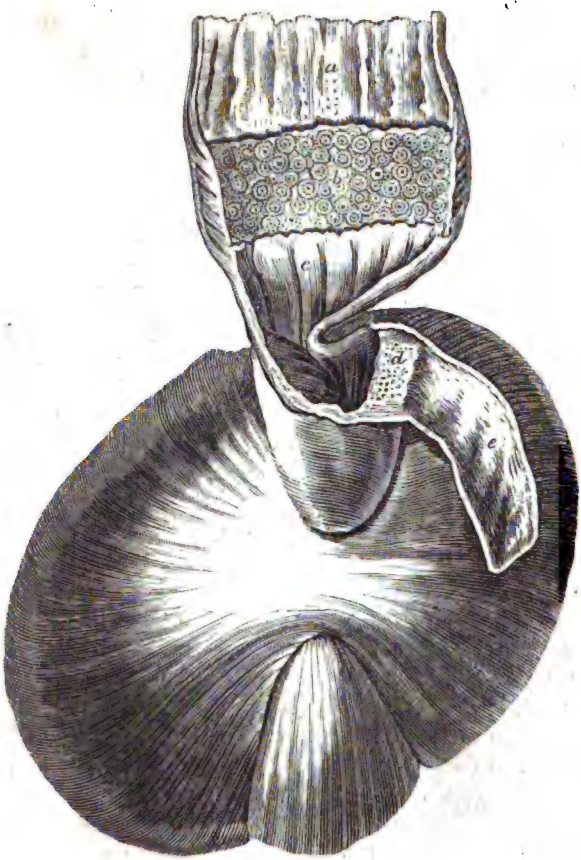


Section of the Stomach of the Ruminant Animal.

passage through the first two. In the third and fourth stomachs, more especially the latter, true digestion takes place. When the food is of such a character as not to require rumination, it can be sent on directly into the third stomach, by the arrangement just described.

In the bird tribes, we see an admirable adaptation of structure to the functions which the digestive organs have to execute. Animals of this class may be divided into the granivorous and the carnivorous. It is in the former, that we are so much impressed with the organization of this part of their economy. The grain on which they feed, although more nutritious than grass, which constitutes the aliment of the herbivorous quadruped, requires equal difficulty in being assimilated to the nature of the being it has to nourish. Added to this, it is in such a condition, that the juices of the digestive organs cannot readily act upon it. The bird having no masticatory apparatus within the mouth, the grain must of necessity be swallowed whole. But we find that lower down in the alimentary tube, a powerful masticatory apparatus exists, which has frequently been considered as a part of the digestive stomach; but really seems destined for mastication only. The following is the arrangement of their gastric apparatus.

Fig. 228.

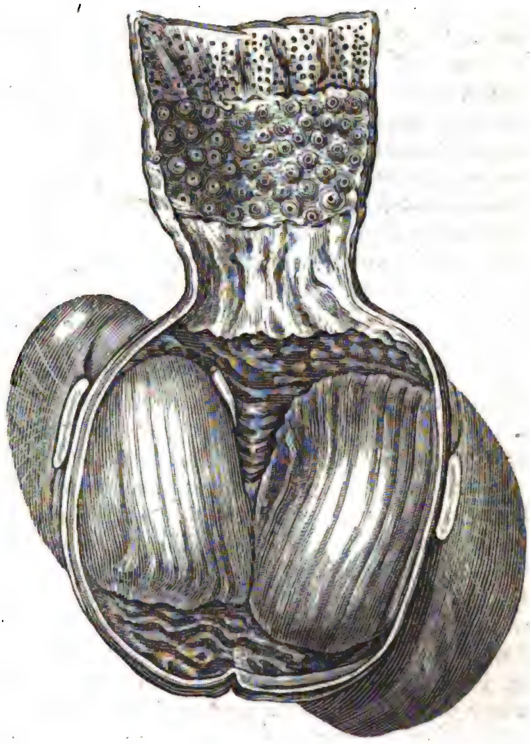


Gastric Apparatus of the Turkey.

The œsophagus terminates at the bottom of the neck in a large sac —*ingluvies*, *crop* or *craw*—which is of the same structure with the œsophagus, but thinner. On the inner side of the crop are numerous glands, with very distinct orifices in large birds, which secrete a fluid to assist in the solution of the food. To the crop succeeds another

cavity, in the shape of a funnel, called *ventriculus succenturiatus*, *proventriculus*, *infundibulum* or *second stomach*. This is seated in the abdomen, and is generally smaller than the former. It is usually thicker than the œsophagus, partly owing to its numerous glands, which are very large and distinct in many birds. In the ostrich, they are as large as the garden-pea, and have very manifest orifices. The infundibulum terminates in the *ventriculus callosus*, *gizzard* or *third stomach* —the most curious of all the parts of the apparatus. Figs. 228 and 229 afford an external and internal view of the gastric apparatus of the turkey; *a*, representing the œsophagus immediately below the crop, covered with cuticle; *b*, the openings of the gastric glands in the second stomach, placed on a surface, that has no cuticular covering; *c*, horny ridges, between the gastric glands and the lining of the gizzard; *d*, a minutely granulated surface between the cavity of the gizzard and duodenum; and *e*, the inner surface of the duodenum. Fig. 228 accurately represents the mode in which the second stomach terminates in the gizzard, and the latter in the duodenum; the gizzard forming a kind of pouch depending from the alimentary canal. The gizzard is usually of a globular figure, flattened at the sides, and is considered to consist of four muscles, remarkable for their great thickness and strength;—a large hemispherical pair at the sides, and a small pair situate at the extremities of the stomach. The gizzard is covered externally by a beautiful tendinous expansion; and is lined by a thick, strong, callous coat, which appears to be epidermous in its character. On this are irregularities, adapted to each other on the opposite surfaces. The cavity of the organ is remarkably small, when compared with its outward magnitude, and its two orifices, represented in Fig. 228, are very near each other. In the pouch formed by the small muscles at the lower part of the gizzard, numerous pebbles are contained, which seem to be indispensable to the digestion

Fig. 229.



Interior of the Gastric Apparatus of the Turkey.

of certain tribes, by acting as substitutes for teeth. In the gizzard of the turkey, two hundred have been found; in that of the goose, one thousand.[1] The prodigious power with which the *digastric muscle* —as it has been termed—acts, and the callous nature of the cuticle, are strikingly manifested by certain experiments, instituted by the *Academia del Cimento*,[2] and by Redi, Réaumur,[3] and Spallanzani.[4] They compelled geese and other birds to swallow needles and lancets, and in a few hours afterwards killed and examined them. The needles and lancets were uniformly found broken off and blunted, without the slightest injury having been sustained by the stomach.

In the carnivorous bird, the food being readily assimilated, in consequence of its analogy to the substance of the animal, the gastric apparatus is as simple as in the carnivorous mammalia. The œsophagus is of great size for receiving the large substances swallowed by these animals, and for enabling the feathers and other matters, that cannot easily be digested, to be rejected by the mouth. The stomach is a mere musculo-membranous sac; but the secretion from it is of a potent character, so as to enable the animal to dispense with mastication, and yet to admit of the stomach and intestines being disposed within a small compass, so as to give them the necessary lightness to fit them for flight.

We can thus, from organization, generally form an idea of the kind of food for which an animal is naturally destined; whether, for example, it is naturally granivorous or carnivorous. There are some striking facts, however, that exhibit the signal changes exerted, even on organization, by restricting an animal to diet of a different character from that to which it has been accustomed; or to one which is foreign to its nature. In birds of prey, the digastric muscle has the bellies, which compose it, so weak, that, according to Sir Everard Home,[5] nothing but an accurate examination can determine its existence. But if a bird of this kind, from want of animal food, be compelled to live upon grain, the bellies of the muscle become so large, that they would not be recognized as belonging to the stomach of a bird of prey. Mr. Hunter kept a sea-gull for a year upon grain, when he found the strength of the muscle much augmented. This wondrous adaptation of structure to the kind of food which the animal is capable of obtaining, is elucidated by the South American and African ostriches. The former is the native of a more productive soil than the latter; and, accordingly, the gastric glands are less complex and numerous; and the triturating organ is less developed.[6]

4. The *intestines* are the lowest portion of the digestive apparatus; constituting a musculo-membranous canal, which extends from the pyloric orifice of the stomach to the anus. The human intestines are six or eight times longer than the body; and hence the number of con-

[1] J. Hunter, Observations on certain parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 119, Philad., 1840; and Roget, Animal and Vegetable Physiology, edit. citat., ii. 126.

[2] Exper. Fatte nell' Acad. del Cimento, 2da ediz., Firenz., 1691.

[3] Mémoir de l'Acad. pour 1752, p. 266 and p. 461.

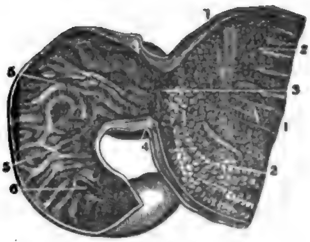
[4] Dissertations relative to the Natural History of Animals and Vegetables, English translation, i. 16, Lond., 1789.

[5] Lectures on Comparative Anatomy, i. 271, Lond., 1814.

[6] Ibid., i. 293.

volutions in the abdominal cavity. They are attached to the vertebral column by folds of peritoneum called *mesentery;* and according to the length of these folds or duplicatures the intestine is bound down, or floats in the abdominal cavity. Their structure is nearly alike throughout: a *mucous* membrane lines them: immediately without this is a *muscular* coat; and, externally, a *serous* coat, formed by a prolongation of the peritoneum. The mucous membrane is soft and velvety, and is the seat of a similar secretion to that of other membranes of the same class. The muscular coat is composed of two planes of fibres, so united that they cannot be separated,—the innermost consisting of circular, and the outermost of longitudinal fibres, the arrangement of which differs in the small and large intestines. The serous or peritoneal coat receives the intestine between two of its laminæ, which, in their passage to it, form the *mesentery*. The serous coat only comes in direct contact with the intestine at the sides and forepart. Behind, or on the mesenteric side, is a vacant space, by which the vessels and nerves reach the intestine. These form their first network between the serous and muscular coats; their second, between the muscular and mucous.

Fig. 230.

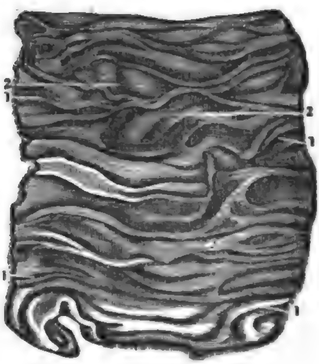


Portion of the Stomach and Duodenum laid open to show their interior.

1, 1. Right or pyloric extremity of stomach. 2, 2. Folds and mucous follicles of mucous coat of stomach. 3. Points into the pylorus. 4. Thickness of the pylorus. 5, 5. Rugæ of the internal coat of the duodenum. 6. Opening of the ductus communis choledochus into the duodenum.

Between the upper four-fifths of the intestinal canal, and the lower fifth, there is a well-marked distinction; not only as regards structure and magnitude, but function. This has given occasion to a division of the canal into *small* and *large intestine;* and these, again, have been subdivided in the various modes that will fall under consideration. As the *small intestine* fills so large a portion of the intestinal canal, its convolutions occupy considerable space in the abdominal cavity, — in the middle, umbilical, and hypogastric regions,—and terminate—in the right iliac region—in the large intestine (see Fig. 210). Its calibre differs in different parts; but it may be regarded on the average as about one inch. It is usually divided, arbitrarily, into three parts;—*duodenum*, *jejunum*, and *ileum.* The *duodenum* is so called, in consequence of its length having been estimated at about twelve fingers' breadth. It is larger than the rest of the small intestine; and has received, also, the name of *second stomach*, and of *ventriculus succenturiatus*. It is more firmly fixed to the body than the other intestines; and does

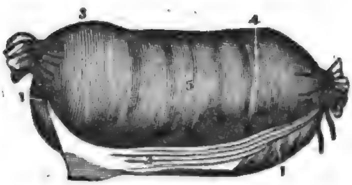
Fig. 231.



Longitudinal Section of the Upper Part of the Jejunum extended under water.

not, like them, float loosely in the abdomen. In its course to its termination in the jejunum, it describes a kind of Italic *c*, the concavity of which looks to the left. From this shape it has been separated into three portions;—the first situate horizontally beneath the liver: the second descending vertically in front of the right kidney; and the third in the transverse mesocolon. Its mucous membrane presents a number of circular folds or rugæ, very near each other, which have been called *valvulæ conniventes.* (Figs. 230 and 231.) By some anatomists, however, this name is not given to the irregular rugæ of its mucous coat; but to those of the lining membrane of the jejunum. The valvulæ are not simple rugæ, passively formed by the contraction of the muscular coat. They are dependent upon the original formation of the mucous membrane; and are not effaced, whatever may be the distension of the intestine. On and between these duplicatures, the different exhalant and absorbent vessels are situate, forming, in part, the *villi* of the intestine, which are from a quarter of a line to a line and two-thirds in length.[1] These villi give to the membrane a velvety appearance, and are not simply composed of exhalants and absorbents, but of nerves; all of which are distributed on an areolar and perhaps erectile tissue. In its healthy state, when successfully injected, the membrane appears to consist almost entirely of a cribriform intertexture of veins. It was formerly believed, that the villi are not supplied with bloodvessels. In each villus, however, there is a minute vascular plexus, the larger branches of which, when distended with blood, may be seen even by the naked eye. Marginal illustration, Fig. 235, exhibits the vessels of one of the intestinal villi of the hare, from Wagner, after an extremely beautiful dry preparation by Döllinger, magnified about 45 diameters. The most obvious use of these villi is to increase the surface from which the secretion is prepared, and from which absorption is effected. Within the membrane

Fig. 232.



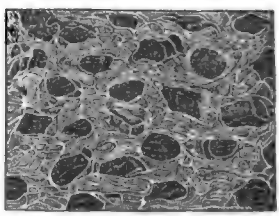
Muscular Coat of the Ileum.

1, 1. Peritoneal coat. 2. A portion of this coat turned off and showing a portion of the longitudinal fibres of the muscular coat adherent to it. 3, 4, 5. Circular muscular fibres in different parts of the intestine.

Fig. 233.

Distribution of Capillaries in the Villi of the Intestine.

Fig. 234.

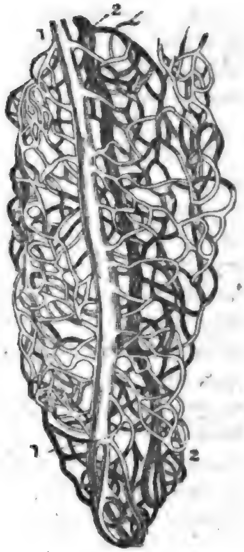


Distribution of Capillaries around Follicles of Mucous Membrane.

[1] J. Müller, Elements of Physiology, by Baly, 2d edit., p. 285, Lond., 1840.

are numerous follicles, which, with the exhalants, secrete a mucous fluid, called by Haller *succus intestinalis*. Their entire number in the whole alimentary canal is estimated by Dr. Horner to be 46,900,000.[1] At about four or five fingers' breadth from the pylorus, the duodenum is perforated by the termination of the biliary and pancreatic ducts, which pour bile and pancreatic fluids into it. (Fig. 219.) Generally, these ducts enter the intestine by one opening; at times, they are distinct, and lie alongside each other. The structure of the duodenum is the same as that of the whole of the intestinal canal. The muscular coat is, however, thicker, and the peritoneal coat only covers its first portion, passes before the second, and is totally wanting in the third, which we have described as included in the transverse mesocolon.

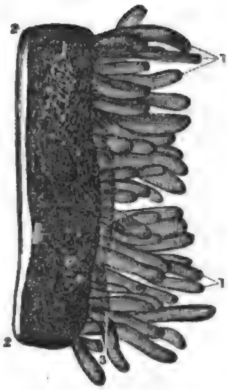
Fig. 235.



Bloodvessels of Villi of the Hare.

1, 1. Veins filled with white injection. 2, 2. Arteries filled with red. A beautiful rete of capillaries between the two.

Fig. 236.



Longitudinal Section of the Jejunum, showing the Villi as seen under the Microscope.

1, 1. Terminal orifices of the villi. 2, 2. Internal coats of the intestine. 3. Peritoneal coat.

The other two portions of the small intestine are of considerable length; the *jejunum* commencing at the duodenum, and the *ileum* terminating, in the right iliac fossa, in the first of the great intestines—the cæcum. They occupy the middle and almost the whole of the abdomen, being surrounded by the great intestine (Fig. 210). The jejunum is so called from being generally found empty; and the ileum from its numerous windings. The line of demarcation, however, between the duodenum and jejunum, as well as between the latter and the ileum, is not fixed: it is an arbitrary division. The jejunum has, internally, the greatest number of valvulæ conniventes and villi. The ileum is the lowest portion. It is of a paler colour, and has fewer valvulæ conniventes. The jejunum is situate at the upper part of the umbilical region; the ileum at the lower part, extending as far as the hypogastric and iliac regions. The mucous membrane of the jejunum and ileum resembles, in all essential respects, that of the duodenum; the valvulæ conniventes are,

Fig. 237.

One of the Glandulæ Majores Simplices of the Large Intestine, as seen from above, and also in a Section.

[1] Special Anatomy and Histology, 7th edit., ii. 55, Philad., 1846.

however, more numerous in the jejunum than in the duodenum; and, in the course of the ileum, they gradually disappear, and are replaced by simple longitudinal rugæ. The villi, too, which are chiefly destined for chylous absorption, abound in the jejunum, but gradually disappear in the ileum. The mucous membrane of both is largely supplied with follicles, called glands of Peyer, Brunner, and Lieberkühn; some, if not all, of which are probably concerned in secreting the *succus entericus*, *succus intestinalis*,—a mucous fluid, to which in digestion Haller attached unnecessary importance. M. Lelut[1] estimates the number of these glands in the small intestine at 40,000. Dr. Horner considers the follicles to be formed, in every instance, of meshes of veins; the arteries entering inconsiderably into their composition,—in about the same proportion as they do in other erectile tissues.[2]

The glands, as they are termed, of the small intestine have long been known under the name of *follicles of Lieberkühn*. These become especially evident if the mucous membrane is inflamed, when they are filled with an opaque whitish secretion, which is absent in the healthy state.[3]

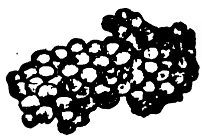
Fig. 238.

Follicles of Lieberkühn filled with tenacious white secretion in Fever. (Boehm.)

The true *glands of Brunn* or *Brunner* are chiefly in the duodenum. They are situate in the submucous tissue, where they form a continuous layer of white bodies surrounding the intestine. They are not larger than a hemp-seed; each consisting of numerous minute lobules, the ducts of which open into a common excretory duct. They are complex structures, differing from the other glands and follicles of the intestines. Nothing is positively known of the nature of their secretion.

The *glands of Peyer* form large patches on the mucous membrane, when they are called *glandulæ agminatæ* and *Peyer's patches*. Examined in a healthy mucous membrane, they have the appearance of circular white, slightly raised spots, about a line in diameter, over which the mucous membrane is least studded with villi, and often wholly without them. On rupturing one of the white bodies a cavity is found, but it has no excretory duct. It contains a grayish-white mucous matter. There are likewise closed solitary glands in both the small and large intestines.[4] The precise use of the glands of Peyer is unknown. Wagner[5] has well observed, that the intimate structure of the whole of these glandular bodies requires farther study, and is almost as little known as their individual functions. There is reason to believe, however, that they secrete a putrescent matter from the blood, which may be concerned in giving to the excrement its peculiar odour; this matter, as in other cases, being formed by cells, which

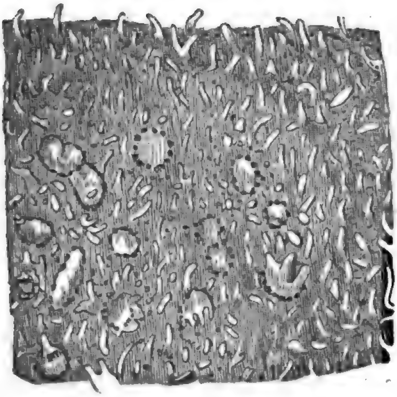
Fig. 239.



Conglomerate Gland of Brunner, magnified 100 times. (Boehm.)

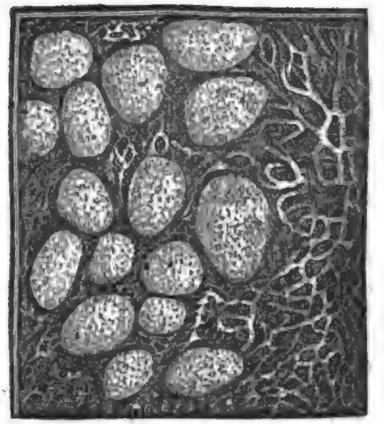
[1] Gazette Médicale, Juin, 1832.
[2] Op. cit., ii. 54. [3] Boehm, cited in Brit. and For. Med. Rev., i. 521, Lond., 1836.
[4] Baly, Lond. Med. Gazette, Mar., 1847.
[5] Elements of Physiology, translated by R. Willis, § 137, Lond., 1842.

Fig. 240.



Portion of one of the Patches of Peyer's Glands from the end of the Ileum: highly magnified. The Villi are also shown. (Boehm.)

Fig. 241.

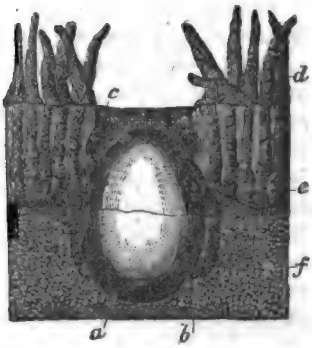


Section of Small Intestine, containing some of the Glands of Peyer, as shown under the microscope.

These glands appear to be small lenticular excavations, containing, according to Boehm, a white, milky, and rather thick fluid, with numerous round corpuscles of various sizes, but mostly smaller than blood globules. The meshes seen in the cut are the ordinary tripe-like folds of the mucous coat.

burst on the free surface of the mucous membrane, and discharge their contents to be mixed with the fæces. The marginal figure, after Bendz,[1] illustrates the morphology of a Peyer's gland.

Fig. 242.



Side View of Intestinal Mucous Membrane of a Cat. (After Bendz.)

a. A Peyer's gland, imbedded in submucous tissue, *f*. *b*. A tubular follicle. *c*. Fossa in mucous membrane. *d*. Villi. *e*. Follicles of Lieberkühn.

The muscular coat of the small intestine is composed of circular and longitudinal fibres; and the outer coat is formed by the prolongation of the peritoneum, which, after having surrounded the intestines, completes the mesentery, by which the gut floats, as it were, in the abdominal cavity.

The *large intestine* terminates the intestinal canal. It is much shorter than the small, and considerably more capacious, being manifestly intended, in part, as a reservoir. It is less loose in the abdominal cavity than the portion of the tube which we have described. It commences at the right iliac fossa (Fig. 210, 9); ascends along the right flank, as far as the under surface of the liver; crosses over the abdomen to gain the left flank, along which it descends into the left iliac region, and

[1] Haandbog i den Almindenige Anatomie, Kjöbenhavn, 1847, cited by Kirkes and Paget, Manual of Physiology, Amer. edit., p. 186, Philad., 1849.

thence through the pelvis, along the hollow of the sacrum, to terminate at the *anus*. Like the small intestine it is divided into three portions; the *cæcum*, *colon*, and *rectum*.

The *cæcum* or *blind gut* is the part of the great intestine into which the ileum opens. It is about four fingers' breadth in length, and nearly double the diameter of the small intestine. It occupies the right iliac fossa, in which it is bound down, so as not to be able to change its position. The extremity of the ileum joins the cæcum, at an angle; and if we examine the interior of the cæcum, at the point of junction, we find a valvular arrangement, which has been called *valve of Tulpius*, *valve of Bauhin*, *ileo-cæcal valve*, &c. Fig. 244 exhibits the nature of this arrangement. At the point of union of the two intestines, a soft eminence exists, flattened from above to below, and elliptical transversely, which is divided into two lips. One of these seems to belong to the ileum and colon—hence called *ileo-colic;* the other to the ileum and cæcum, and termed *ileo-cæcal.* From the disposition of these lips a valve results, so constituted, that the lips, which form it, separate when the fæcal matters pass from the small to the large intestine; whilst they approximate, cross, and completely prevent all retrogression, when the fæces tend to pass from the great intestine to the small. At the extremities of the valve are small tendons, which give it strength, and have been termed *fræna* or *retinacula of the valve of Bauhin.*

Although this valvular arrangement prevents the ready return of the excrementitious matter into the small intestine, we have many pathological opportunities for discovering that it is not effectual in all cases. In stricture of the large intestine, stercoraceous vomiting is a frequent phenomenon, and there have been cases of substances, thrown into the rectum, having been evacuated by the mouth.

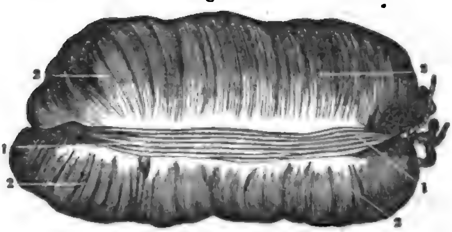
At the posterior and left side of the cæcum, a small process detaches itself, called, from its resemblance to a worm, *appendix vermiformis;* and, from its connexion with the cæcum, *appendix cæci.* It is convoluted, variable in length, and attached, by its sides, to the cæcum. Its free extremity is impervious; the other opens into the back part of the cæcum. This appendage has all the characters of an intestine. Various hypotheses have been indulged regarding its uses. Some have conceived it to be a reservoir for the fæces; but its diminutive size, in the human subject, precludes this idea: others have thought, that it secretes a ferment, necessary for fæcal formation; and others, again, a mucus for preventing the induration, that might result from the detention of the fæces in the cæcum. The opinion—that it is a mere *vestige* of the useful and double cæca, which exist in certain animals—is as philosophical as any. M. de Blainville,[1] indeed, regards it as the true cæcum; and what is named the cæcum as the commencement of the colon. It is manifestly of little importance, as it has been found wanting or obliterated in many subjects, and has been extirpated repeatedly with impunity. The cæcum is said to be wanting in all animals that hybernate. It is small in the Carnivora; very large and long in the Solidungula, Ruminantia and Rodentia; in which,—as will

[1] De l'Organisation des Animaux, &c., Paris, 1825.

be seen hereafter,—there is reason to believe, that digestion of the aliment, which has escaped change higher up, occurs.

The *colon* is by much the longest of the large intestines, (Fig. 210.) It is a continuation of the cæcum, from which it cannot be distinguished; but is considered to commence at the termination of the ileum. From the right iliac fossa it ascends along the right lumbar region, over the kidney, to which it is connected. It is, in this part, called *colon dextrum, ascending* or *right lumbar colon*. From the kidney it passes forwards and crosses the abdomen in the epigastric and hypochondriac regions, being connected to the duodenum. This portion is called *great arch of the colon, colon transversum*. The right portion of the great arch is situate under the liver and gall-bladder; and hence is found tinged yellow after death, owing to the transudation of bile. The left portion of the arch is situate under the stomach; and, immediately below it, are the convolutions of the jejunum. In the left hypochondre, the colon turns backward under the spleen, and descends along the left lumbar region, anterior to the kidney, to which it is closely connected. This portion is termed *colon sinistrum, descending* or *left lumbar colon*. In the left iliac region, it forms two convolutions, which have been compared to the Greek ς, or to the Roman s; and hence this part of the intestine has been designated *sigmoid flexure, Roman* s, or *iliac turn of the colon*. This flexure varies greatly in length in different persons, extending frequently into the hypogastric region, and, in some instances, as far as the cæcum. The colon, through its whole extent, is fixed to the body by the mesocolon.

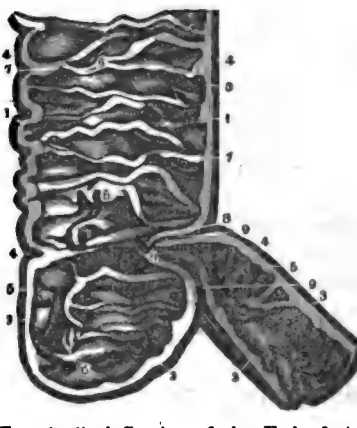
Fig. 243.



Muscular Coat of the Colon, as seen after the removal of the Peritoneum.

1, 1. One of its three bands of longitudinal muscular fibres. 2, 2. Circular fibres of the muscular coat.

Fig. 244.



Longitudinal Section of the End of the Ileum, and of the Beginning of the Large Intestine.

1, 1. Portion of the ascending colon. 2, 2. Cæcum. 3, 3. Lower portion of ileum. 4, 4. Muscular coat, covered by peritoneum. 5, 5. Areolar and mucous coats. 6, 6. Folds of mucous coat at this end of the colon. 7, 7. Prolongations of areolar coat into these folds. 8, 8. Ileo-colic valve. 9, 9. Union of the coats of the ileum and colon.

The coats of the great intestine are the same in number and structure as those of the small; but are thinner, and not as easily separable by dissection. The mucous membrane is less villous and velvety. The most characteristic difference, however, in their general appearance, is the pouched or cellular aspect of the former. These pouches are reservoirs for excre-

ment, and in them it becomes more indurated, by the absorption of the fluid portions. In torpor of this part of the intestinal canal, the fæces are retained, at times, so long, that they form hard balls or scybala; and not unfrequently occasion the inflammation of the lining membrane of the large intestine, which constitutes dysentery. The longitudinal muscular fibres are concentrated into three ligamentous bands or fasciculi, which run the whole length of the intestine. These being shorter than the intestine, pucker it, and are the occasion of the pouched or saccated arrangement. The inner or circular muscular fibres are, like those of the small intestine, uniformly spread over the surface, but are stronger. Lastly, on the great intestine, especially the colon, are numerous processes of the peritoneum containing fat, and hence called *appendiculæ epiploïcæ* and *appendiculæ pinguedinosæ.* These are seen in greatest abundance on the right and left lumbar portions of the colon.

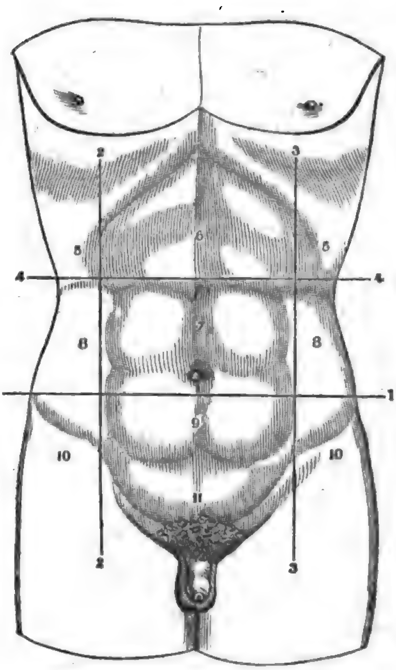
The *rectum* terminates the intestinal canal, and extends from the end of the colon to the anus. It commences about the fifth lumbar vertebra, and descends vertically into the pelvis, following the concavities of the sacrum and coccyx; and, consequently, is not straight, as its name would import. At its upper part, there are a few appendiculæ epiploïcæ; and a small duplicature of the mesentery, called *mesorectum*, attaches it to the sacrum. It differs from the other intestines in becoming wider in its progress downwards, and in its parietes being thicker. The lower part of the mucous membrane exhibits several longitudinal folds or rugæ, called "columns," which have been considered as the effect of the contraction of the circular fibres of the muscular coat. At the lower ends of the wrinkles between the columns are small pouches, from two to four lines in depth, the orifices of which point upwards. They are occasionally the seat of disease, and, when enlarged, give rise to painful itching. The nature of this affection was first pointed out by Dr. Physick, and the remedy consists in slitting them open. The longitudinal fibres of the muscular coat have a different arrangement from that which exists in the other portions of the large intestine. They are distributed over the whole surface, as in the small intestine,—or rather, as in the œsophagus. At the anus, an arrangement of the muscular coat prevails, which has been pointed out by Professor Horner.[1] The longitudinal fibres, having reached the lower margin of the internal sphincter, turn under this margin between it and the external sphincter, and then ascend upwards for an inch or two in contact with the mucous coat, into which they are finally inserted by fasciculi, which form the base of the columns of the rectum: many of the fibres, however, terminate also between the fasciculi of the circular fibres. The circular fibres are more and more marked, as they approach the outlet, and, by circumscribing the margin of the anus, they form the sphincter ani muscle. Immediately within the anus is the widest portion of the rectum; and, in this, accumulations of indurated fæces sometimes take place in old people to a surprising extent, owing to torpor of the muscular powers concerned in the expulsion of the fæces. The mucous coat of the rectum is thick and red, and abounds in follicles.

[1] General Anatomy and Histology, 7th edit., ii. 50, Philada., 1846.

Lastly; there are a few muscles, which are concerned in the act of expelling the fæces. These require a short notice. 1. The *sphincter ani*, *coccygeo-anal* muscle, which keeps the anus constantly closed, except during defecation. 2. The *levator ani*, *subpubio-coccygeus*, which, with the next muscle, constitutes the floor of the pelvic and abdominal cavities. It restores the anus to its place, when pushed outwards during defecation. 3. The *coccygeus*, *ischio-coccygeus*, which assists the levator ani in supporting or raising the lower extremity of the rectum; and 4. The *transversus perinei*, *ischio-perineal* muscle, some fibres of which unite both with the bulbo-cavernosi and with the sphincter ani muscles; and, consequently, it is associated slightly with the action of both one and the other.

In regard to the intestinal canal, we find, that man holds a medium place between the carnivorous and herbivorous animal, although approximating more to the latter. In the carnivorous—for reasons more than once mentioned—it is unnecessary that the food should remain long; accordingly, the canal is very short. In the herbivora, on the other hand, and for opposite reasons, the canal is long, and there is generally a large cæcum and a pouched colon. Cuvier[1] has given tables of the length of the digestive tube, compared with that of the body; but where the comparison has been applied to man, the length of the body has included that of the legs. Instead, therefore, of the canal, in him, being considered to bear the proportion of six to one, it ought to be doubled, or be regarded as twelve to one; a proportion somewhat greater than prevails in the simiæ or ape tribe. It is not, however, always in length, that the canal of the herbivorous exceeds that of the omnivorous animal; but as a general rule, it may be affirmed, that its capacity is much more considerable.

Fig. 245.



View of External Parietes of Abdomen, with the position of the Lines drawn to mark off its Regions.

1, 1. Line drawn from the highest point of one ilium to the same point of the opposite one. 2, 2. Line drawn from the anterior superior spinous process to the cartilages of the ribs. 3, 3. A similar one for the opposite side. 4, 4. Line drawn perpendicularly to these, and touching the most prominent part of the costal cartilages, thus forming nine regions. 5, 5. Right and left hypochondriac regions. 6. Epigastric region. 7. Umbilical region. 8, 8. Right and left lumbar regions. 9. Hypogastric region. 10, 10. Right and left iliac regions. 11. The lower part of the hypogastric, sometimes called pubic.

5. The *abdomen*, in which the principal digestive organs are situate, and whose parietes

[1] Leçons d'Anatomie Comparée, Paris, 1799.

exert considerable influence on the digestive function, requires a brief description. It is the division of the body, which is betwixt the thorax and pelvis; is bounded, above, by the arch of the diaphragm; behind, by the vertebral column; laterally, and anteriorly, by the abdominal muscles; and, below, by the ossa ilii, os pubis, and the cavity of the pelvis.

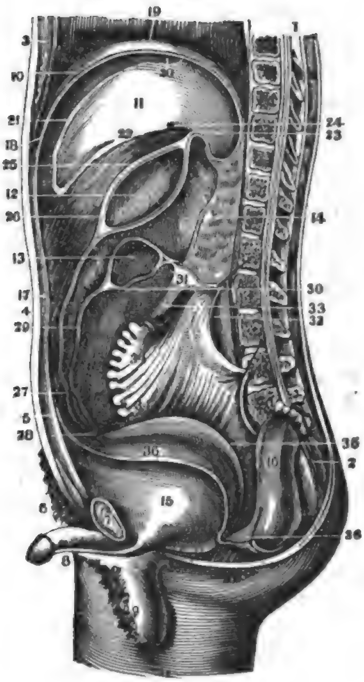
To connect the knowledge of the internal parts of the abdomen with the external, it is customary to mark certain arbitrary divisions on the surface, called *regions*. (Fig. 245.) The *epigastric region* is at the upper portion of the abdomen, under the point of the sternum, and in the angle formed by the cartilages of the ribs. The *hypochondriac regions* are covered by the cartilages of the ribs. These three regions—the epigastric, and right and left hypochondre—constitute the upper division of the abdomen, in which are seated the stomach, liver, spleen, pancreas, duodenum, and part of the arch of the colon. The space surrounding the umbilicus, between the epigastric region and a line drawn from the crest of one os ilii to the other, is the *umbilical region*. Here the small intestines are chiefly situate. This region is bounded by lines, raised perpendicularly to the spine of the ilium; and the lateral portions on the outside of these lines, form the *iliac regions*, behind which, again, are the *lumbar regions* or *loins*. In these, the colon and kidneys are chiefly situate. The *hypogastric* is, likewise, divided into three regions,—the *pubic* in the middle, in which is the bladder; and an *inguinal* on each side.

The muscles that constitute the abdominal parietes, are,—first of all, *above*, the diaphragm, which is the boundary between the thorax and abdomen, convex towards the chest, and considerably concave towards the abdominal cavity. *Below*, if we add the pelvic cavity,—which, as it contains the rectum, and muscles concerned in the evacuation of the fæces, it may be proper to do,—the cavity is bounded by the perineum, formed chiefly of the levatores ani and coccygei muscles. *Behind*, *laterally*, and *anteriorly*, from the lumbar vertebræ round to the umbilicus, the parietes consist of planes of muscles, and aponeuroses in superposition, united at the median line, by a solid, aponeurotic band, extending from the cartilago-ensiformis of the sternum to the pubes, called *linea alba*. The *abdominal muscles*, properly so called, are,—reckoning the planes from within to without,—the greater *oblique muscle*, *lesser oblique*, and *transversalis*, which are situate chiefly at the sides of the abdomen;—and the *rectus* and *pyramidalis*, which occupy the anterior part. The *greater oblique*, *obliquus externus*, *costo-abdominalis*; *lesser oblique*, *obliquus internus*, *ilio-abdominalis*, and *transversalis*, *transversus abdominis*, *lumbo-abdominalis*, support and compress the abdominal viscera; assist in the evacuation of the fæces and urine, and in the expulsion of the fœtus; besides other uses, connected with respiration and the attitudes. The *rectus*, *pubio-sternalis* or *sterno-pubialis*; and the *pyramidalis* or *pubio-subumbilicalis*, are more limited in their action, and compress the forepart of the abdomen; besides having other functions.

Lastly, a serous membrane—the *peritoneum*—lines the abdomen, and gives a coat to most of the viscera. The mode, in which its various

reflections are made, is singular, but easily intelligible from the accompanying figure (Fig. 246). It has neither beginning nor end, constitut-

Fig. 246.



1. Section of the spinal column and canal. 2. Section of the sacrum. 3. Section of the sternum, &c. 4. Umbilicus. 5. A section of the linea alba and abdominal muscles. 6. Mons veneris. 7. Section of the pubis. 8. Penis divided at the corpora cavernosa. 9. Section of the scrotum. 10. Superior right half of the diaphragm. 11. Section of the liver. 12. Section of the stomach, showing its cavity. 13. Section of the transverse colon. 14. Section of the pancreas. 15. Section of the bladder, deprived of the peritoneum. 16. Rectum cut off, tied and turned back on the promontory of the sacrum. 17. Peritoneum covering the anterior parietes of the abdomen. 18. Peritoneum on the inferior under side of the diaphragm. 19. Peritoneum on the convex side of the diaphragm. 20. Reflection of peritoneum from diaphragm to liver. 21. Peritoneum on front of liver. 22. The same, on its under surface. 23. Hepato-gastric omentum. 24. A large pin passed through the foramen of Winslow into the cavity behind the omentum. 25. Anterior face of the hepato-gastric omentum, passing in front of the stomach. 26. The same membrane leaving the stomach to make the anterior of the four layers of the great omentum. 27, 28. Junction of the peritoneum from the front and back part of the stomach, as they turn to go up to the colon. 29. Gastro-colic, or greater omentum. 30. Separation of its layers, so as to cover the colon. 31. Posterior layer passing over the jejunum. 32. Peritoneum in front of the right kidney. 33. Jejunum cut off and tied. 34, 34. Mesentery cut off from the small intestines. 35. Peritoneum reflected from the posterior paries of the bladder to the anterior of the rectum. 36. Cul-de-sac between the bladder and the rectum.

Reflections of the Peritoneum, as shown in a Vertical Section of the Body.

ing, like all serous membranes, a shut sac; and, in reality, having no viscus within it. If we assume the diaphragm as the part at which it commences, we find it continued from the surface of that muscle over the abdominal muscles, 5; then reflected, as exhibited by the curved line, over the bladder, 15; and, in the female, over the uterus; thence over the rectum, 16; the kidney, enveloping the intestine, 13, and constituting, by its two laminæ, the mesentery, 34; giving a coat to the liver, 11; and receiving the stomach, 12, between its duplicatures. The use of this membrane is to fix and support the different viscera; to constitute, for each, a pedicle, along which the vessels and nerves may reach the intestine; and to secrete a fluid, which enables them to move readily upon each other. When we speak of the cavity of the peritoneum, we mean the inside of the sac; and when it is distended with fluid, as in ascites, the fluid is contained between the peritoneum lining the abdominal muscles, and that which forms the outer coat of the intestines. The *omenta* or *epiploa* are fatty membranes, which hang over the face of the bowels; and are reflections, formed by the peritoneum after it has covered the stomach and intestines. Their names sufficiently indicate their position:—the *lesser epiploon* or *omentum*,—the *omentum*

hepato-gastricum; the *greater* or *gastro-colic;* and the *appendices* or *appendiculæ epiploicæ;* which last have already been referred to, and may be regarded as so many small epiploons.

The abdomen is entirely filled by the contained viscera. There are several apertures in it; three, above, in the diaphragm, for the passage of the œsophagus, vena cava inferior, and aorta; one anteriorly in the course of the linea alba, which is closed after birth,—the *umbilicus;* and two anteriorly and inferiorly; the one—the *abdominal, inguinal;* or *supra-pubian ring*—which gives passage to the vessels, nerves, &c., of the testicle; and the other—the *crural arch*—through which the vessels and nerves pass to the lower extremity. Lastly, two others exist in the inferior paries, for the passage of the obturator vessels and nerves, and sciatic vessels and nerves, respectively.

Such is a brief view of the various organs concerned in digestion. To this might have been added the general anatomy of the liver and pancreas,—each of which furnishes a fluid, that is a material agent in the digestive process,—and of the spleen, which has been looked upon by many as inservient, in some manner, to the same function. As, however, the physiology of these organs will be considered in another place, we defer their anatomy for the present.

2. FOOD OF MAN.

The articles, inservient to the nourishment of man, have usually been considered to belong entirely to the animal and vegetable kingdoms; but there seems to be no sufficient reason for excluding those articles of the mineral kingdom that are necessary for the due constitution of the different parts of the body. Generally, the term *food* or *aliment* is applied to substances, which, when received into the digestive organs, are capable of being converted into chyle; but, from this class again, the products of the mineral kingdom—chloride of sodium, phosphorus, sulphur, and lime, either in combination or separately—cannot, with entire propriety, be excluded. There are numerous tribes who feed at particular seasons more especially on mineral substances. Kessler affirms, that the quarriers on the Kyffhäuser, in northern Thuringia, spread a Steinbutter—"rock butter," on bread, which they eat with appetite; and Humboldt relates, among many other instances, that of the Ottomacs, who, during the periodical rise of the Orinoco and Meta, when the taking of fish ceases—a period of two or three months' duration—swallow great quantities of earth. They found piles of clayballs in pyramidal heaps in the huts, and Humboldt was informed, that an Ottomac would eat from three-quarters of a pound to a pound and a quarter in a day. Some of this earth was analyzed by M. Vauquelin, and found to contain no organic matter. It would appear, that the practice of eating earth exists in many parts of the torrid zone, among indolent nations, who inhabit the finest and most fertile regions of the globe. But it is not confined to them; for the same writer affirms, that in the north, by information communicated by Berzelius and Retzius, hundreds of cartloads of earth containing infusoria are annually consumed by the country people in the most remote parts of

Sweden as bread meal, and even more as a luxury—like tobacco—than as a necessary. In Finland, the earth is occasionally mixed with the bread. It consists of empty shells of animalcules, so small and soft as not to cranch perceptibly between the teeth, filling the stomach, but affording no real nutriment. Many similar cases are recorded by Humboldt.[1]

Animals are often characterized by the kind of food on which they subsist. The *carnivorous* feed on flesh; the *piscivorous* on fish; the *insectivorous* on insects; the *phytivorous* on vegetables; the *granivorous* on seeds; the *frugivorous* on fruits; the *graminivorous* and *herbivorous* on grasses; and the *omnivorous* on the products of both the animal and vegetable kingdoms. In antiquity, we find whole tribes designated according to the aliment they chiefly used. Thus, there were the Æthiopian and Asiatic *ichthyophagi* or fish-eaters; the *hylophagi*, who fed on the young shoots of trees; the *elephantophagi*, and *struthiophagi*, elephant and ostrich-eaters, &c. &c.

We have already shown, that the digestive apparatus of man is intermediate between that of the carnivorous and the herbivorous animal; that it partakes of both, and that man may, consequently, be regarded *omnivorous*; that is, capable of subsisting on both the products of the animal and the vegetable kingdom;—an important capability, seeing, that he is destined to live in arctic regions, in which vegetable food is not to be met with, as well as in the torrid zone, which is more favorable for vegetable than animal life.

The nature of the country must, to a great extent, regulate the food of its inhabitants; for although commerce can furnish articles of luxury, and many, which are looked upon as necessaries, no nation is entirely indebted to it for its supplies. Besides, numerous extensive tribes of the human family are denied the advantages of commerce, and compelled to subsist on their own resources. This is the main cause why the Esquimaux, Samoiedes, &c., live wholly on animal food; and why the cocoa-nut, plantain, banana, sago, yam, cassava, maize and millet, form chief articles of diet with the natives of torrid regions.

In certain countries, the scanty supply of the useful and edible animals has given occasion to certain prohibitory dietetic rules and regulations, which have been made to form part of the religious creed, and, of course, are most scrupulously observed. Thus, in Hindoostan, animal food is not permitted to be eaten; but the milk of the cow is excepted. Accordingly, to insure the necessary supply of this fluid, the cow is made sacred; and its destruction a crime against religion. Amongst the laws of the Egyptians are similar edicts, but they seem to have been chiefly enacted for political purposes, and not in consequence of the unwholesome character of the interdicted articles. The same remark applies to many of the dietetic rules of Moses, for the regulation of the tables of the Hebrews. Blood was forbidden, in consequence, probably, of the fear entertained, that it might render the people too familiar with that fluid, and diminish the horror inculcated against

[1] Ansichten der Natur; translated under the title of Aspects of Nature, by Mrs. Sabine, Amer. edit., p. 159, Philad., 1849.

shedding it: the parts of generation were excluded from the table, because the taste, if indulged, might interfere with the reproduction of the species, &c. &c.

We have said, that, in his arrangement of the digestive organs, man is intermediate between the carnivorous and the herbivorous animal. Not the slightest ground is afforded by anatomy for the opinion of Rousseau, that man was originally herbivorous; or for that of Helvetius,[1] that he was exclusively carnivorous. Broussonet affirms, that he is more herbivorous than carnivorous, since, of his thirty-two teeth, twenty resemble those of the herbivorous, whilst twelve only resemble those of the carnivorous animal. Accordingly, he infers, that, in the origin of society, the diet of man must have been exclusively vegetable. Mr. Lawrence,[2] too, concludes, that, whether we consider the teeth and jaws, or the immediate instruments of digestion, the human structure closely resembles that of the simiæ—the great archetypes, according to Lord Monboddo[3] and Rousseau, of the human race,—all of which are, in their natural state, herbivorous.

Again:—a wide discrepancy between man and animals is observed in the variety of their aliments. Whilst the latter are generally restricted to either the animal or vegetable kingdom, and to but a small part of either, man embraces an extensive range, and by means of his culinary inventions can convert a variety of articles from both kingdoms into materials of sustenance. But it has been argued by those, who are sticklers for *the natural*, that man probably confined himself, primitively, like animals, to one kind of food; that he adhered to this whilst he remained in his *natural state*, and that his omnivorous practices are a proof of his degeneracy. Independently, however, of all arguments deduced from organization, experience sufficiently shows the inaccuracy of such assertions. If we trace back nations to their state of infancy, we find, that then, as in their more advanced condition, their diet was animal, or vegetable, or both, according to circumstances. Of this fact we have some signal examples in a part of the globe where the lights of civilization have penetrated to a less extent than in most others; and where the influence of circumstances that prevailed in ancient periods has continued, almost unmodified, until the present time. Agatharchides[4] describes the rude tribes, who lived on the coast of the Red Sea, and subsisted on fish, under the name *ichthyophagi*. Along both banks of the Astaboras, which flows on one side of Meroë, dwelt another nation, who lived on roots of reeds growing in the neighbouring swamps. These roots they cut to pieces with stones, formed them into a tenacious mass, and dried them in the sun. Close to them were the *hylophagi*, who lived on the fruits of trees, vegetables growing in the valleys, &c. To the west of these were hunting nations, who fed on wild animals, which they killed with the arrow. There were, also, other tribes, who lived on the flesh of the elephant and ostrich,—*elephanto-*

[1] De l'Homme, ii. 23, Londres, 1775.
[2] Lectures on Physiology, Zoology, &c., p. 221, Lond., 1819.
[3] On the Origin and Progress of Language, Pt. i. Book 2, Chap. 2, Edinb., 1773.
[4] De Rubro Mare, in Hudson's Geograph. Minor., i. 37.

phagi and *struthiophagi*. Besides these, he mentions another and less populous tribe, who fed on locusts, which came in swarms from the southern and unknown districts. The mode of life, with the tribes described by Agatharchides, does not seem to have varied for the last two thousand years. Although cultivated nations are situated around them, they have made no progress themselves. Hylophagi are still to be met with. The Dobenahs, the most powerful tribe amongst the Shangallas, still live on the elephant; and, farther to the west, dwells a tribe, which subsists in the summer on the locust; and, at other seasons, on the crocodile, hippopotamus, and fish.[1]

In the infancy of society, as in his own infancy, man was perhaps almost wholly carnivorous; as the tribes least advanced in civilization are at the present day. For a time, he may, in most situations, have confined himself to the vegetable banquet prepared for him by his bounteous Maker; but, as population increased, the means of subsistence would become too scattered for him, and it would be necessary to crowd together a number of nutritious vegetables into a small space, and to cultivate the earth, so as to multiply its produce; but this would imply the existence of settled habits and institutions which could only arise after society had made progress. Probably, much before this period, it would have been discovered, that certain of the beasts of the forest, and of the birds of the air, and some of the insect tribes, could minister to his wants, and form agreeable and nutritious articles of diet; and thus would arise their adoption as food. On the coasts of the ocean, animal food was perhaps employed from the period of their first settlement; as well as on the banks of the large streams which are so common in Asia,—the cradle of mankind. The fish, left upon the land after the periodical inundations of the rivers, or thrown on the seacoast, would minister to their necessities, without the slightest effort on their part; and, hence, they would have but little incentive to mental or corporeal exertion. This is the cause of the abject condition of the ichthyophagous tribes of old; and of their comparatively low state of civilization at the present day.[2] Again:—savages, in various parts of the globe, live by the chase or the fishery; and must, consequently, be regarded as essentially carnivorous. It would not, however, be justifiable, to regard barbarism as the *natural* state of man; nor is it clear what the different writers on this point of anthropology have meant by the term. The Author of nature has invested him with certain prerogatives, one of which is the capability of rendering the organized kingdom subservient to his wishes and necessities; and, by the invention of the culinary art, of converting various organized bodies into wholesome and agreeable articles of diet, which thus become as *natural* to him as the restriction to one species of aliment is to the animal.

It has been remarked, that the exclusive or predominant use of animal or of vegetable food has a manifest effect upon the physical and moral powers. Buffon affirms, that if man were obliged to abstain from flesh in our climates, he could not exist, nor propagate his kind.

[1] Bruce, Travels, 3d edit., v. 83.
[2] The Author, in Amer. Med. Intelligencer, i. 99, Philad., 1838.

Others, again, have depicted a state of ideal innocence, in the infancy of society, when he lived, as they conceive, entirely on vegetables;

"His food the fruits; his drink the crystal well;"

unsolicitous for the future in consequence of the abundant subsistence spread before him; independent; and always at peace with his fellows, and with animals; but he gradually sacrificed his liberty to the bonds of society; and cruelty, with an insatiable appetite for flesh and blood, were the first fruits of a depraved nature. Either immediately or remotely, all the physical and moral evil, by which mankind are afflicted, arose from these carnivorous practices. "The principal patrons of this twaddle, in modern times"—says Dr. Fletcher—"to say nothing of Pythagoras and the ancients—have been Gassendi, Rousseau, Wallis, Lamb, and Newton; the last of whom, in the plenitude of his infatuation, asserts that *real* men have never yet been seen, nor ever will be, till they shall be content to subsist entirely on herbs and fruits and distilled water."[1] In point of fact, we find, that the inhabitants of countries, in which mankind are accustomed to be omnivorous, or to unite animal with vegetable diet, are those most distinguished for both mental and corporeal endowments. The tribes, which feed altogether on animal food,—as the Laplanders, Samoiedes, Esquimaux, &c.,—are far inferior, in both these respects, to the European, or Europeo-American; and the same may be said, although not to the like extent, of the various tribes in whose diet animal food predominates,—as the Indian inhabitants of our own continent. A similar remark is applicable to those, who live almost exclusively on vegetables, as the Hindoos, millions of whom are kept in subjection by a few Europeans.[2]

Attempts have frequently been made to refer the nutrient properties of all articles of diet to a particular principle of a constant character, which, alone, of all the elements, is entirely capable of assimilation. Haller[3] conceived this to be jelly;—Dr. Cullen[4] thought it to be oily, or saccharine, or what seemed to be a combination of the two;—Becker, Stahl, Fordyce,[5] &c., to be mucilage; M. Dumas,[6] mucus; and M. Hallé, a hydro-carbonous oxide very analogous to gummi-saccharine matter![7] It is probable, that there is no such special principle as the one contended for; and that, in all cases, in the formation of the chyle or reparative fluid, which is separated from it, the food is resolved into its elements. To this conclusion we are necessarily impelled, when we reflect, that chyle can be formed from both animal and vegetable substances. In an early part of this work, occasion was taken to mention, that all organized tissues, animal and vegetable are reducible into nearly the same ultimate elements,—oxygen, hydrogen, carbon, and

[1] Rudiments of Physiology, Part ii., *a*. p. 121, Edinb., 1836.
[2] Lawrence's Lectures, edit. cit., p. 216.
[3] Elementa Physiologiæ, Lib. xix., Sect. 3, Bernæ, 1764.
[4] Institutions of Medicine, Part i., Physiology, § 211, Edinb., 1785.
[5] Treatise on the Digestion of Food, p. 84, 2d edit., Lond., 1791.
[6] Principes de Physiologie, i. 187, Paris, 1806.
[7] Tiedemann, Physiologie des Menschen, iii. 95, Darmstadt, 1836.

nitrogen. Great light has been thrown on this subject, in recent periods, by the labours of the organic chemist. These have shown, that the chief proximate principles of animal tissues, and those that have been regarded as highly nutritious amongst vegetables, have almost identically the same composition; and are modifications of protein.[1] The following tables from Liebig[2] exhibit the striking similarity in constitution, and in the proportion of constituents, of different animal and vegetable compounds of organization.

Animal proximate principles, according to Mulder.

	Albumen.	Fibrin.	Casein.
Carbon,	54·84	54·56	54·96
Hydrogen,	7·09	6·90	7·15
Nitrogen,	15·83	15·72	15·80
Oxygen,	21·23	22·13	21·73
Sulphur,	0·68	0·33	0·36
Phosphorus,	0·33	0·36	
	100·00	100·00	100·00

Vegetable proximate principles, according to Scherer and Jones.

	Albumen, from wheat.	Fibrin.	Casein or Legumin.
Carbon,	55·01	54·603	54·138
Hydrogen,	7·23	7·302	7·156
Nitrogen,	15·92	15·809	15·672
Oxygen, Sulphur, Phosphorus,	21·84	22·286	23·034
	100·00	100·000	100·000

As the different parts of organized bodies contain a considerable portion of nitrogen, a question has arisen regarding its source; some believing, that it is obtained from the food, others by respiration.

M. Magendie[3] instituted experiments with the view of determining the nutritive qualities of non-nitrogenized substances. They consisted in feeding animals, for the necessary time, on a diet whose chemical composition was rigidly determined. He fed a dog, three years old and in good condition, on pure white sugar and distilled water. For seven or eight days, the animal appeared to thrive well, was lively, and ate and drank with avidity. In the second week, it began to fall off, although its appetite continued good, and it ate six or eight ounces of sugar in the twenty-four hours. In the third week, it became emaciated, its strength diminished, its gaiety was gone, and its appetite impaired. An ulcer formed on each eye, at the centre of the cornea, which subsequently perforated it, and allowed the humours to escape. The emaciation, as well as loss of strength, went on progressively increasing; and, although the animal ate daily three or four ounces of sugar, the debility became so great, that it could neither chew, swallow, nor execute the slightest movement. It died on the thirty-second day of the experiment. On dissection, the fat was found to have entirely

[1] See page 47.
[2] Animal Chemistry, Gregory's and Webster's edit., pp. 100, 283, and 301, Cambridge, Mass., 1842.
[3] Précis Elémentaire, 2de édit. ii. 488, Paris, 1825.

disappeared; the muscles were reduced to less than five-sixths of their ordinary size; the stomach and intestines were much diminished, and powerfully contracted; and the gall and urinary bladders filled with fluids not proper to them. These were examined by M. Chevreul, who found them to possess almost all the characters of the bile and urine of herbivorous animals. The urine, in place of being acid, as it is in the carnivora, was sensibly alkaline, and presented no trace of uric acid or phosphates. The bile contained a considerable proportion of picromel, like that of the ox and herbivora in general. The excrements contained very little nitrogen, which they usually do in abundance.

A second dog was subjected to the like regimen, and with similar results. He died on the thirty-fourth day of the experiment. A third experiment, having eventuated in the same manner, M. Magendie concluded that sugar alone is incapable of nourishing the dog. In all these cases, ulceration of the cornea occurred, but not exactly at the same period of the experiment. He next endeavoured to discover, whether these effects might not be peculiar to sugar; or whether non-nitrogenized substances, generally considered nutritious, might not act in the same manner. He took two young and vigorous dogs, and fed them on olive oil and distilled water. For fifteen days they were apparently well; but, after this, the same train of phenomena supervened as in the other cases, except that there was no ulceration of the cornea. They died about the thirty-sixth day of the experiment. Similar experiments were made with gum Arabic, and with butter—one of the animal substances that do not contain nitrogen. The results were identical.

Although the character of the excrements passed by the different animals indicated that the substances were well digested, M. Magendie was desirous of establishing this in a positive manner. Accordingly, after having fed animals for several days on oil, gum, or sugar, he opened them, and found that each of these substances was reduced to a particular kind of chyme in the stomach; and that all afforded an abundant supply of chyle;—that from oil being of a manifest milky appearance, and that from gum or sugar transparent, opaline, and more aqueous than the chyle from oil; facts which prove, that if the various substances did not nourish the animals, the circumstance could not be attributed to their not having been digested. These results, M. Magendie thought, render it likely, that the nitrogen, found in different parts of the animal economy, is originally obtained from the food. This, however, is doubtful. We have no proof, that the animals died simply from privation of nitrogen. It is, indeed, probable, that it had little or no agency in the matter, for there seems to be no sufficient reason why it should not have been procured from the air in respiration, as well as from that contained between the particles of the sugar, where this substance was administered. It must be recollected, moreover, that the subjects of these experiments were dogs;—animals which, in their natural state, are carnivorous, and, in a domestic state, omnivorous; and that they were restricted to a diet foreign to their nature, and one to which they had not been accustomed. Ought we, under such circumstances, to be surprised, that they should sicken, and fall off?

In the period that elapsed between the publication of the first and second editions of his *Précis Elémentaire de Physiologie*, M. Magendie found that his deductions were not, perhaps, as absolute or demonstrative as he had at first imagined; and additional experiments induced him to conclude,—as Dr. Bostock[1] afterwards did, without being aware, apparently, of his observation,—"that variety and multiplicity of articles of food constitute an important hygienic rule." "This," M. Magendie[2] adds, "is indicated to us by our instinct, as well as by the changes that wait upon the seasons, as regards the nature and kind of alimentary substances." The additional facts, detailed by M. Magendie, are the following:—A dog, fed at discretion on pure wheaten bread, and drinking common water, does not live beyond fifty days; whilst another, fed exclusively on military bread—*pain de munition*—seems to suffer in no respect. Rabbits or Guinea-pigs, fed on a single substance, as wheat, oats, barley, cabbage, carrots, &c., commonly die, with every mark of inanition, in a fortnight; and, at times, much earlier. When the same substances are given together, or in succession, at short intervals, the animals continue in good keeping. An ass, fed on rice, lived only fifteen days, refusing his food for the last few days; whilst a cock was fed upon boiled rice for several months without his health suffering. Dogs, fed exclusively on cheese, and others on hard eggs, lived for a long time; but they were feeble and lean, losing their hair, and their whole appearance indicated imperfect nutrition. The substance, which, when given alone, appeared to support the rodentia[3] for the greatest length of time, was muscular flesh.

Lastly, M. Magendie found, that if an animal had subsisted for a certain time on a substance, which, taken alone, is incapable of nourishing it,—on white bread, for instance, for forty days,—it is useless, at the end of that time, to vary his nourishment, and restore him to his accustomed regimen. He will feed greedily on the new food presented to him; but continues to fall off; and dies at the same period as he would probably have done, if maintained on his exclusive regimen. That these effects are not owing to privation of nitrogen, the same observer[4] has since been amply satisfied. As chairman of a committee appointed to inquire into the nutritive properties of gelatin, he reported that gelatin, albumen, and fibrin—all of which are highly nitrogenized—when taken separately, nourish animals for a limited period only, and imperfectly. They generally soon excite so insurmountable a disgust that the animals would rather die than partake of them. These experiments led to the too hasty conclusion, that the gelatinous tissues are incapable of conversion into blood. "The gelatinous substance," says Liebig,[5] "is not a compound of protein; it has no sulphur, no

[1] Physiology, 3d edit., p. 561, Lond., 1836.
[2] Op. citat., ii. 494.
[3] The *rodentia* are gnawing animals, having large incisors in each jaw, with which they divide hard substances. They are the *rongeurs* of the French naturalists. The squirrel, mouse, rat, Guinea-pig, hare, rabbit, beaver, kangaroo, porcupine, &c., belong to this division.
[4] Comptes Rendus, Août, 1841. Similar results were obtained by the Amsterdam Commission, in Het Instituut, No. ii. 1843, pp. 97–114, cited by Mr. Paget, Brit. and For. Med. Rev., April, 1845, p. 563.
[5] Animal Chemistry, Amer. edit., by Webster, p. 124, Cambridge, Mass., 1842.

phosphorus, and contains more nitrogen or less carbon than protein. The compounds of protein, under the influence of the vital energy of the organs that form the blood, assume a new form, but are not altered in composition; whilst these organs, as far as our experience reaches, do not possess the power of producing compounds of protein, by virtue of any influence, from substances that contain no protein. Animals, which were fed exclusively on gelatin, the most highly nitrogenized element of the food of carnivora, died with symptoms of starvation." "In short," he adds, "gelatinous tissues are incapable of conversion into blood." Such too, seems to be the opinion of Professor Bérard.[1] Yet it has been shown above, that fibrin and albumen—both compounds of protein—when exhibited singly to animals, nourished them as imperfectly as gelatin; and there is some reason to believe, that it is mainly on chemical considerations that the value of gelatin as a nutriment has been much underrated. "Such persons only," says Professor Mulder,[2] "as are under the influence of prejudice (making their experiments with dogs—animals which, according to the account of the gelatin committee, prefer to starve in the midst of gelatin, rather than touch it), such persons only as deny the results of innumerable observations, will refuse to gelatin its place among useful nutritive substances." And he adds: "I have thought it necessary, before closing this short account of gelatin, to express my opinion of the experiments by which pure gelatin is rejected as food:—namely, that these experiments have taught me nothing but how experiments ought *not* to be made." It is somewhat singular, too, that most of those who deny much nutrient property to gelatin are of opinion, that the nutritious properties of different articles of vegetable food may be generally estimated by the proportion of nitrogen they contain, and on this principle tables have been formed by several experienced chemists,—by Boussingault, Schlossberger, Kemp,[3] and Professor Horsford,[4] of Cambridge, Massachusetts. The latter gentleman, especially, has furnished us with the results of elaborate investigations into the nature of different kinds of vegetable food, based upon the amount of nitrogen. The tables of Boussingault and Horsford are considered by Professor Frerichs,[5] of value; whilst those of Schlossberger and Kemp are declared to be practically useless, because no regard was paid to the quantity of water in the fresh condition; and for the strange reason, "that the nitrogen found in most of the substances analyzed that contain gelatin is no measure of the quantity of the hæmatogenetics or blood-forming constituents!"

Independently of showing the necessity of variety of food for animal sustenance, the experiments of M. Magendie exhibit some singular anomalies; and sufficiently demonstrate, that we have yet much to learn

[1] Archives Générales de Médecine, Février, 1850, p. 247.

[2] The Chemistry of Vegetable and Animal Physiology, by G. J. Mulder, &c., p. 328, Edinb. and Lond., 1849.

[3] Annal. der Chemie und Pharmacie, B. lvi. s. 78–94; see also, Philosophical Magazine for Nov., 1845.

[4] Philosophical Magazine, for Nov., 1846, p. 365.

[5] Art. Verdauung, in Wagner's Handwörterbuch der Physiologie, 19te Lieferung, s. 732, Braunschweig, 1848.

on the subject. A great deal, doubtless, depends on the habits of the particular animal or individual; and on the morbid effects excited by completely changing the function of assimilation. It has been long known, that if a man, previously habituated to both animal and vegetable diet, be restricted exclusively to one or the other, he will fall off, and become scorbutic; and yet, that he is capable of subsisting on either one or the other exclusively, provided the restriction has been enforced from early infancy, has been sufficiently shown by the reference made to carnivorous and herbivorous tribes existing in different regions of our globe. The importance of variety of diet is illustrated by the experiments made by Dr. Stark,[1] upon his own digestive powers, and to which he ultimately became a martyr. His object was to discover the relative effect of various simple substances, when used exclusively for a long space of time as articles of food. The system, he found, was in all cases reduced to a state of extreme debility, and there was not a single aliment, that was capable, of itself, of sustaining the vigour of the body for any considerable period. By this kind of regimen Dr. Stark is said to have so completely ruined his own health, as to bring on premature death.

In accordance with his views, that nitrogenized food is alone capable of forming organized tissue; and that the non-nitrogenized food is inservient to respiration only, Liebig thus classifies aliments:—

Nitrogenized Food or Plastic Elements of Nutrition.	*Non-nitrogenized Food or Elements of Respiration.*	
Vegetable Fibrin,	Fat,	Pectin,
" Albumen,	Starch,	Bassorin,
" Casein,	Gum,	Wine,
Flesh,	Cane Sugar,	Beer,
Blood.	Grape Sugar,	Spirits.
	Sugar of Milk,	

These views, however, demand further proof. They are not confirmed by what is observed in chylification. In the small chyliferous vessels, more fat, which is a non-nitrogenized substance, is found than can be accounted for by the adipose matter in the food; and of the conversion of the amylaceous and saccharine matters in the food to oil during the digestive function a striking example has been published by M. Köss.[2] A workman was killed on a railroad after having eaten a full meal of bread and grapes only. On examining his body, the process of chymification was found to have been in full activity; and in those portions of the small intestine, which the chyme had reached, the mucous membrane was dotted with white points, which, on closer examination, were found to be owing to drops of oil in the epithelial cells surrounding the extremities of the villi. As the chyle proceeds along the lacteals, the proportion of fat becomes less and less, whilst that of the nitrogenized matters increases; hence nitrogen must have been obtained, and a conversion have taken place of non-nitrogenized into nitrogenized matters. (See PHYSIOLOGY OF CHYLOSIS.) On the other hand it has been shown, that the followers of Liebig maintain,

[1] The Works of the late Wm. Stark, M. D., &c., by Dr. J. C. Smyth., Lond., 1787.
[2] Cited in London Med. Gazette, Oct., 1846.

that gelatin is not convertible into a proteinaceous substance; and hence it is not classed by them amongst the elements of nutrition; yet it contains an unusual amount of nitrogen. It has been affirmed, that all nitrogenized food, according to the above classification of Liebig, is reduced in the stomach to the form of albumen; which is said to resemble the gum of plants in being the raw material, as it were, out of which the various fabrics of the body are constructed. Yet this is not demonstrated; and it is probable that the conversion into albumen takes place more especially in the chyliferous vessels.

The alimentary substances, employed by man, have generally been classed either according to the ultimate chemical elements entering into their composition; or to the chief proximate principle or compound of organization. In the former case, they have been grouped into:—1, those that contain nitrogen, carbon, hydrogen, and oxygen;—2, those that contain carbon, hydrogen, and oxygen; and 3, those that contain neither nitrogen nor carbon. The first class will comprise most animal and many vegetable substances; the second, vegetable substances chiefly; whilst water is perhaps the only alimentary matter that belongs to the third.

The division proposed by M. Magendie,[1] and adopted by Dr. Paris,[2] is according to the proximate principles, which predominate in the aliment.

1. *Amylaceous aliments;* wheat, barley, oats, rice, rye, Indian corn, potato, sago, salep, peas, haricots, lentils, &c.
2. *Mucilaginous aliments;* carrot, salsify, beet, turnip, asparagus, cabbage, lettuce, artichoke, melon, &c.
3. *Saccharine aliments;* the different kinds of sugar, figs, dates, raisins, &c.
4. *Acidulous aliments;* the orange, currant, cherry, peach, raspberry, strawberry, mulberry, grapes, prunes, pears, apples, tomatos, &c.
5. *Oily and fatty;* cocoa, olives, sweet almonds, hazelnuts, walnuts, animal fats, oils, butter, &c.
6. *Caseous aliments;* the different species of milk, cheese, &c.
7. *Gelatinous aliments;* the tendons, aponeuroses, skin, areolar tissue, the flesh of very young animals, &c.
8. *Albuminous aliments;* the brain, nerves, eggs, &c.
9. *Fibrinous aliments;* comprehending the flesh and blood of different animals.

To these proximate principles *gluten* may be added, which has been termed the most animalized of vegetable principles. According to Dr. Prout,[3] it is separable into two portions, analogous to gelatin and albumen. It is very generally met with, although only in small proportion, in the vegetable kingdom;—in all the farinaceous seeds, in the leaves of cabbage, cress, &c.; in certain fruits, flowers, and roots, and in the green fecula of vegetables in general; but it is especially abundant in wheat, and imparts to wheaten flour the property of fermenting and making bread. Of the nutritious properties of gluten, distinct from other principles, we know nothing precise: the superior nutritious powers of wheaten flour over those of all other farinaceous substances

[1] Précis, &c., ii. 34.

[2] A Treatise on Diet, 3d edit., p. 182, Lond., 1837; and art. Dietetics, in Cyclopædia of Practical Medicine, Amer. edit., Philad., 1845.

[3] Chemistry, Meteorology, and the Function of Digestion, (Bridgewater Treatise,) Amer. edit., p. 558, Philad., 1834.

sufficiently attest, that, in combination with starch, it is highly nutritive.

Dr. Prout[1] arranges alimentary principles in four great divisions—the *aqueous*, *saccharine*, *oleaginous*, and *albuminous*. This has been taken as the basis for a classification by Dr. Pereira,[2] who admits twelve divisions:—the *aqueous*, *mucilaginous* or *gummy*, *saccharine*, *amylaceous*, *ligneous*, *pectinaceous*, *acidulous*, *alcoholic*, *oily* or *fatty*, *proteinaceous*, *gelatinous*, and *saline*. By the combination of these *alimentary principles* and *simple aliments*, our ordinary articles of food or *compound aliments* are formed. In this classification, the proteinaceous and gelatinous aliments are separated. The following simple arrangement is, perhaps, as little liable to objection as any:—

I. *Nitrogenized aliments*, (Albuminous of Prout.)	Fibrinous (Glutinous?) Albuminous. Caseinous. Gelatinous.
II. *Non-nitrogenized aliments.*	Amylaceous. Saccharine. Oleaginous.

The second division might be still farther simplified; for amylaceous aliments are convertible into sugar during the digestive process; and of both—as has been seen,—oleaginous matter may be formed.

Water forms the basis of all drinks; but it frequently contains in addition other substances. These have been classed as follows:—1. *Water*, of different kinds. 2. *Vegetable and animal juices and infusions*, as lemon-juice, orange-juice, whey, tea, coffee, &c. 3. *Fermented liquors*, as wines, beer, cider, perry, &c.; and 4. *Alcoholic liquors*, as brandy, alcohol, kirsch-wasser, rum, gin, whisky, arrack, &c. &c. Dr. Pereira[3] has proposed the following more complete classification:—1. *Mucilaginous*, *farinaceous* or *saccharine* drinks. 2. *Aromatic* or *astringent* drinks. 3. *Acidulous* drinks. 4. Animal broths, or drinks containing *gelatin* and *osmazome*. 5. *Emulsive* or *milky* drinks; and 6. *Alcoholic* and other *intoxicating* drinks. Water—as has been seen—is considered by him amongst the alimentary principles.

An inquiry into the different properties of these various liquids does not belong to the physiologist. It may be remarked, however, that the arguments regarding the *natural* have been extended to this variety of aliments; and it has been contended, that water is "the most natural drink;" and that all others, which are the products of art, ought to be avoided. The remarks, already made on this subject, are sufficient. Water was, doubtless, at one period, the only beverage of man, as nakedness, the use of raw aliment, and the most profound ignorance of the universe, were his original condition; but no one will be presumptuous enough to declare, that he ought to continue naked, abjure cookery, and be plunged into his primitive darkness, on the plea that all these

[1] On the Nature and Treatment of Stomach and Renal Diseases, Amer. edit., from the 4th revised London edit., ii. 354, Philad., 1843.

[2] A Treatise on Food and Diet, Amer. edit. by Dr. C. A. Lee, p. 38, New York, 1843.

[3] Op. cit., p. 189.

changes are so many artificial sophistications.[1] Water is, unquestionably, sufficient for all his wants; but the moderate use of fermented liquors, even if habitual, except in particular constitutions, is devoid, we think, of every noxious result. They are grateful; and many of them are even directly nutritious from the undecomposed sugar and mucilage which they contain. For this reason beer has been termed, not inaptly, "liquid bread."[2] With regard to distilled spirits, no evil would result from their total rejection from the table. Although they may, by their action on the digestive organs, be indirect means of nutrition, they contain no alimentary principle. They are received into the vessels of the stomach by imbibition; and always produce undue stimulation, when taken to any amount. This may be productive of little or no mischief, provided they be only used occasionally; but, if taken habitually, serious visceral disorder may sooner or later ensue.

Lastly.—There are certain substances called *condiments* employed in diet, not simply because they are nutritive,—for many of them possess no such properties,—but because, when taken with food capable of nourishing, they promote its digestion, correct some injurious property, or add to its sapidity. Dr. Paris has divided these into *saline*, *spicy* or *aromatic*, and *oily*. It may be remarked, however, that certain articles are called, at times, *aliments;* at others, *condiments*, according as they constitute the basis or the accessory to any dish;—such are cream, butter, mushrooms, olives, &c. The advantage of condiments in animal digestion is exemplified by many cases. The bitter principle, which exists in grasses and other plants, appears to be essential to the digestion of the herbivora,—acting as a natural stimulant; and it has been found that cattle do not thrive upon grasses which are destitute of it. Of the value of salt to the digestive function of his cattle, the agriculturist has ample experience; and the salt licks of our country show how grateful this natural stimulant is to the beasts of the forests. Charcoal, administered with fat,—as is done, in rural economy for fattening poultry, in many parts of England,—exhibits the advantage of administering a condiment; the charcoal of itself contains no nourishment, but it puts the digestive function in a condition for separating more nutritious matter from the food taken in, than it could otherwise do. A similar effect is produced by the plan,—adopted for the same purpose in certain parts of Great Britain,—of cramming the animal with walnuts, coarsely bruised, with the shell. This is asserted, by many rural economists, to be the most effectual plan for fattening poultry speedily; the coarse shell, in passing along the mucous membrane of the intestines, seems to stimulate it to augmented action, and a more bountiful separation of nutritious matter is the consequence. The aromatic condiments act in a similar manner.

In regard to the quantity of food required for human sustenance, nothing definite can be laid down. It must differ according to habit, constitution, way of life, age, sex, &c. The diet scale of the British navy affords a good average for the adult male in busy life, who requires

[1] See an article by the author in the American Quarterly Review, ii. 422, Philad., 1827; and Fletcher, op. citat., p. 121.

[2] Kitchener, Invalid's Oracle, Amer. edit., p. 136, New York, 1831.

more aliment than those in less active employment. It consists of from 31 to 35½ ounces of dry nutritious matter daily; of which 26 ounces are vegetable and the rest animal,—9½ ounces of salt meat, or 4½ ounces of fresh, being the proportion of the latter. This is found to be an ample allowance. In prisons a reduction must be made. In a convict ship, which took out 433 prisoners to New Holland, in 1802, the mortality was trifling, and the general health good, although the prisoners were allowed only 16 ounces of vegetable food, and 7½ ounces of animal food per day. Whenever the allowance is more restricted, or a due admixture of animal and vegetable food is not permitted, the health suffers, and signs of scorbutus appear;—a result occasionally witnessed in our public eleemosynary institutions, when under the care of ignorant and too economical superintendents. It would seem, from the experiments of M. Chossat,[1] that under such circumstances an incapability is induced of digesting even the inadequate amount supplied.

The smallest quantity of food upon which life is known to have been actively supported was in the case of Cornaro, who affirms that he took no more than 12 ounces a day, and that chiefly vegetable, for a period of sixty-eight years. Of the amount that can be eaten by the glutton, we have surprising instances on record,—the stomach acquiring, at times, an enormous capacity. Captain Parry relates the case of a young Esquimaux, who was permitted to devour as much as he chose. It amounted, in the twenty-four hours, to thirty-five pounds of various kinds of aliment, including tallow candles; and a case has been published of a Hindoo, who could eat a whole sheep at a time.

These few remarks on the food of man will serve as an introduction to the mode in which the various digestive processes are accomplished. The more intimate consideration of alimentary substances, with their comparative digestibility, &c., will be found in another work of the author, to which the reader is referred.[2]

3. PHYSIOLOGY OF DIGESTION.

The detail entered into regarding the various organs concerned in digestion will have led to the anticipation, that the history of the function must be multiple and complex. The food is not, in the case of the animal—as it is in that of the vegetable—placed in immediate contact with the being to be nourished; an act of volition is, consequently, necessary to procure and to convey it to the upper orifice of the digestive tube. This act of volition is excited by an internal sensation—that of hunger—which indicates the necessity for taking fresh nourishment into the system. The appetite and hunger, with the prehension or reception of food, must therefore be regarded part of the digestive operations. These may be enumerated and investigated in the following order:—1st. *Hunger*, or the sensation that excites us to take food. 2dly. *Prehension of food*, the voluntary muscular action, that introduces it into the mouth. 3dly. *Oral* or *buccal digestion*, comprising the changes

[1] Referred to at page 558.
[2] Human Health, p. 179, Philad., 1844. For different dietaries, &c., see Pereira, Treatise on Food and Diet, Amer. edit., by Dr. C. A. Lee, p. 222, New York, 1843; and Art. Diet Scale, in the author's Med. Dictionary, 7th edit., Philad., 1848.

wrought on the food in the mouth. 4thly. *Deglutition*, or the part taken by the pharynx and œsophagus in digestion. 5thly. *Chymification*, or the action of the stomach on the food. 6thly. The *action of the small intestine*. 7thly. The *action of the large intestine*. And, 8thly. *Defecation* or *the expulsion of the fæces*. All these processes are not equally concerned in the formation of chyle. It is separated in the small intestine: the first six, therefore, belong to it;—the remainder relate only to the excrementitious part of the food. The digestion of solid food requires all the eight processes: that of liquids is more simple; comprising only thirst, prehension, deglutition, the action of the stomach, and that of the small intestine. Fluid rarely reaches the large intestine.

In inquiring into this important and interesting function, we shall first attend to the digestion of solids, and afterwards to that of liquids.

4. DIGESTION OF SOLID FOOD.

a. *Hunger.*

Hunger is an internal sensation, the seat of which is invariably referred to the stomach. Like every internal sensation, it proceeds from changes in the very texture of the organ. It is not produced by any external cause; and to it are applicable all those observations, that were made on internal sensations in general. In its slightest condition, it is merely an *appetite*, (ορεξις; Germ. E s s l u s t;) but if this be not heeded, the painful sensation of *hunger* (*Fames*, λιμος), supervenes, which becomes more and more acute and lacerating unless food is taken. If this be the case, however, the uneasiness gradually abates; and if sufficient be eaten, a feeling of satiety is produced. The sensation usually occurs, in the healthy state, after the stomach has been for some time empty, having finished the digestion of substances taken in at the previous meal. Habit has a great effect in regulating this recurrence; the appetite always appearing about the time at which the stomach has been accustomed to receive food. This artificial desire may be checked by various causes;—by the exciting or depressing passions, the sight of a disgusting object, or any thing that occasions intense mental emotion; or it may be appeased by filling the stomach with substances that contain no nutritious properties. As, however, the feeling of true hunger arises from the wants of the system, the natural and instinctive sensation soon appears, and cannot be long postponed by any of these means. Hence, it has been proposed to make a distinction between *appetite* and *hunger;* applying the former term to the artificial, the latter to the natural, desire. In these respects, there is certainly a wide distinction between them, as well as in the capriciousness, which occasionally characterizes the former, and gives rise to singular and fantastic preferences.

The sensation of hunger varies in intensity according to different circumstances. It is more powerful in the child and youth than in one who has attained his full height. In the period of second childhood, it is urgent,—probably owing to the diminished power of assimilation requiring that more aliment should be received into the stomach. In disease, the sensation is generally suppressed, and its place often supplied by loathing or disgust for food: at times, again, its intensity makes

it a true disease, as in bulimia, and pica; in the latter of which, the appetite is, at times, irresistibly directed to substances, which the person never before relished, or are not edible,—as chalk, earth, slate-pencil, &c. The appetite is also modified by exercise or inactivity, and other circumstances extrinsic and intrinsic,—regular exercise, and the exhilarating passions; a cold and dry atmosphere, &c., augmenting it, whilst it is blunted by opposite circumstances. Long continued exertion, with a scanty supply of nourishment, if not continued so long as to injure the tone of the stomach, produces, occasionally, in adults, a voracious appetite and rapid digestion. Mr. Hunter has quoted, in illustration of this point, the following extract from Admiral Byron's narrative. After describing the privations he had suffered when shipwrecked on the coast of South America, the Admiral incidentally refers to their effect upon his appetite. "The governor ordered a table to be spread for us with cold ham and fowls, which only we three sat down to, and in a short time despatched more than ten men with common appetites would have done. It is amazing, that our eating to that excess we had done from the time we first came among these kind Indians had not killed us, as we were never satisfied, and used to take all opportunities for some months after, of filling our pockets, when we were not seen, that we might get up two or three times in the night to cram ourselves."[1]

Authors have distinguished the local from the general phenomena of hunger; but many of their assertions on these points appear imaginative. We are told by M. Adelon[2] and others,[3] that the stomach becomes contracted, and that this change is effected by the action of its muscular coat alone;—the mucous or lining membrane becoming wrinkled, and the peritoneal coat, externally, permitting the organ to retire between its laminæ. Such, MM. Tiedemann and Gmelin[4] assert, is the result of their observations. M. Magendie,[5] however, affirms, that after twenty-four, forty-eight, and even sixty hours complete abstinence, he has never witnessed this contraction of the organ. It had always considerable dimension, especially in its splenic portion; and not until after the fourth or fifth day did it appear to him to close upon itself, diminish greatly in capacity, and slightly change its position; and these effects were not observed unless the fasting was rigorously maintained.

At the time that the stomach changes its shape and situation, the duodenum is said to be drawn slightly towards it; its parietes appear thicker,—and the mucous follicles and nervous papillæ project more into the interior. Its cavity is void of food, and contains only a little saliva, mixed with bubbles of air; a small quantity of mucus; and, according to some, a little bile and pancreatic juice, which the traction of the duodenum has caused to flow into it.

Much dispute has arisen as to whether the circulation of the blood in

[1] Byron's Voyage, p. 181; and Hunter on the Animal Economy, p. 196.
[2] Physiologie de l'Homme, ii. 396.
[3] Rullier, Art. Faim, in Dict. de Médecine, tom. viii., Paris, 1823.
[4] Die Verdauung nach Versuchen, u. s. w.; or French translation, by A. J. L. Jourdan, Paris, 1827.
[5] Op. citat., ii. 25.

the stomach experiences any mutation. M. Dumas[1] was of opinion, that when the organ is empty, it receives less blood than when full; either on account of the great flexion of the vessels in the former case, or on account of the compression experienced by the nerves in consequence of the contracted state of the organ. He thinks that, under such circumstances, a part of the blood sent to it reflows into the liver, spleen, and omentum; and he regards these organs as diverticula for the blood of the stomach, especially as the liver and spleen are then less compressed, and the omentum more extensive, owing to the retraction of the stomach. Bichat, however, denies both the fact and its explanation. He affirms, that on opening animals suffering under hunger, he never observed the vessels of the stomach less full of blood, the mucous membrane less florid, or the vessels of the omentum more turgid. Is it not true, he adds, that the vessels of the stomach are more flexuous when the organ is empty? being, as well as the nerves, connected with the serous coat, they are unaffected by changes of size in the organ; and besides, the retraction of the stomach could never be great enough to compress the nerves. He denies, moreover, that the liver and spleen are more free, and the omentum larger, whilst the stomach is empty, as the abdominal parietes contract in the same proportion as the stomach. Magendie,[2] however, contests this last assertion of Bichat; and affirms, on the faith of positive experiments, that the pressure sustained by the abdominal viscera is in a ratio with the distension of the stomach. If the stomach be full, the finger, introduced into the cavity of the abdomen through an incision in its parietes, will be strongly pressed upon, and the viscera forced towards the opening; whilst, if it be empty, the pressure as well as the tendency of the viscera to escape through the opening is considerable. During the state of vacuity of the organ, he remarked that the different reservoirs in the cavity of the abdomen,—the bladder and gall bladder,—were more easily filled by their proper fluids. With regard to the quantity of blood circulating through the stomach in the empty and full state,—he is disposed to believe, that the organ receives less in the former condition; but that in this respect it does not differ from other abdominal viscera.

The *general* effects, said to be produced by hunger, in contradistinction to the *local*, are;—debility and diminished action of every organ; the circulation and respiration are less frequent; the heat of the body sinks; the secretions diminish, and all the functions are exerted with more difficulty, if we except absorption, which it is affirmed, and with much probability, is augmented. If the abstinence be so long protracted as to cause death, the debility of the functions becomes real, and not sympathetic. Respiration and circulation languish; all the animal functions totter; whilst absorption continues, and the blood is supplied by the decomposition of the different organs,—the fat, the various liquid matters and the tissues of the organs being successively subjected to its action. It is obvious, however, that, with the drain perpetually taking place, this state of affairs cannot exist long; the blood becomes diminished in quantity, and insufficient in every respect to vivify the organs; the functions of the brain are perverted, and, in

[1] Principes de Physiologie, Paris, 1806.

[2] Précis, &c., edit. cit., ii. 26.

many instances, furious delirium has closed the scene; whilst, at others, the miserable sufferer has sunk passively into the sleep of death. Occasionally, again, so dreadfully painful are the sensations caused by protracted privation of food, that the most violent antipathies and dearest affections have been overcome; and numerous instances have occurred in which the sufferer has attacked his own species, friends, children, and even his own person. The horrible picture of the shipwreck, by Byron,[1] is not a mere romance. It is a narrative of facts that have actually occurred, expanded somewhat by the imagination of the poet.

Dr. James Currie[2] has related the case of a person, who died of inanition from stricture of the œsophagus, the particulars of which may exemplify the phenomena presented by some of those who perish from abstinence. The records of such cases are rare. From the 17th of October to the 6th of December, the patient was supported, without the aid of the stomach, by means of broth clysters; and was immersed in a bath of milk and water. At one period he had a parched mouth: a blister discharged only a thin, coagulable lymph; and the urine was scanty, extremely high-coloured, and intolerably pungent. The heat of the body was natural and nearly uniform from first to last; and the pulse was perfectly natural until the last days. His sleep was sound and refreshing; spirits even; and intellect unimpaired, until the four last days of existence, when clysters were no longer retained. Vision was deranged on the first of December, and delirium followed on the succeeding day; yet the eye was unusually sensible, and the sense of touch remarkably acute. The surface and extremities were at times of a burning heat; at others, clammy and cold. On the fourth, the pulse became feeble and irregular, and respiration laborious; and, in ninety-six hours after all means of nutrition as well as medicine had been abandoned, he ceased to breathe. He was never much troubled by hunger. Thirst was, at first, troublesome, but it was relieved by the tepid bath. This was a case in which the patient sank tranquilly to death. In others, the distressing accompaniments above described, are met with; and the death is that of a furious maniac.

The period at which the fatal event may occur from protracted abstinence is dependent on many circumstances. As a general rule the young and robust will expire sooner than the older; and this will have to be our guidance in questions of survivorship, where several individuals have perished together from this cause. The picture, drawn by Dante of the sufferings and death of Count Ugolino della Gherardescha, who saw his sons successively expire before him from hunger, is in this respect true to nature.

> "Now when our fourth sad morning was renew'd,
> Gaddo fell at my feet, outstretch'd and cold,
> Crying:—'Wilt thou not, father! give me food?'
> There did he die; and as thine eyes behold
> Me now, so saw I three fall, one by one,
> On the fifth day and sixth; whence in that hold,
> I, now grown blind, over each lifeless son
> Stretch'd forth mine arms. Three days I call'd their names,
> Then Fast achieved what Grief not yet had done."
>
> "INFERNO," canto xxxiii.

[1] Don Juan, canto ii., 58.

[2] Medical Reports, &c., Amer. edit., Philad., 1808.

In some experiments on inanition undertaken by M. Chossat,[1] on pigeons and turtle doves, the following general phenomena were observed. Commonly, the animal remained calm during the first half or two-thirds of the period. It then became more or less agitated, and this state continued as long as the temperature remained elevated. On the last day of life, however, the restlessness ceased, and gave place to stupor. When set at liberty, it sometimes looked round with astonishment, without attempting to fly, and at times closed its eyes, as if in a state of sleep. Gradually, the extremities became cold, and the limbs so weak as to be no longer able to sustain it in the standing posture. It fell over on one side, and remained in any position in which it might be placed, without attempting to move. Respiration became slower and slower; the general weakness increased, and the insensibility became more profound; the pupils dilated; and life became extinct,—at times in a calm and tranquil manner; at others, after convulsive actions, producing opisthotonic rigidity of the body.

He endeavoured to discover the effect of age in modifying the continuance of life during inanition, but was unable to ascertain the relative ages of the turtle doves, the subjects of his experiments; he endeavoured, however, to form some estimate—although, obviously, a fallacious one—from their relative weights, classing them as "young," "middle-aged," or "adult," according as their weights were beneath 120 grammes, from 120 to 160, or above 160. The following table is interesting, however, by showing the duration of life, and the loss of substance during inanition, in animals of different weights.

	Weight of the Body.		Loss of the Body.			
	Weight at commencement.	Weight at death.	Entire absolute loss.	Proportional loss in 1000 parts.	Daily proportional loss.	Duration of life.
	Gram.	Gram.	Gram.			
a. Young . .	110·42	82·84	27·58	0·250	0·081	3·07
b. Middle-aged	143·62	91·60	52·02	0·362	0·059	6·12
c. Old . . .	189·36	101·61	87·75	0·463	0·035	13·36

The entire absolute loss, and the proportionate loss, were much greater in the heavier animals; the daily loss was by much the most rapid in the lightest; and it is probable, that this was owing to the more rapid waste which takes place in the young.

The sensation of hunger resembles every other sensation in the mode in which it is accomplished. There must be impression, conduction, and perception. That the encephalon is the organ of the last part of the process is proved by all the arguments used in the case of the internal sensations in general. Without its intervention in this, as in every other case, no sensation can be accomplished. The stomach is the organ in which the impression is effected; and by means of the nerves this impression is conveyed to the spinal marrow and encephalon. The eighth pair or pneumogastric nerves have generally been

[1] Recherches Expérimentales sur l'Inanition, Paris, 1843; noticed in Brit. and For. Med. Rev., April, 1844, p. 347.

regarded as the agents of this transmission; and it has been affirmed by Baglivi, Valsalva, Haller, Dumas, Legallois, Chaussier, and others, that if they be divided in the neck, although the stomach may be favourably circumstanced, in other respects, for the developement of the impression of hunger, and the encephalon for its reception, there is no sensation; but MM. Leuret and Lassaigne,[1] Dr. John Reid,[2] Nasse,[3] and Longet,[4] deny, that such effect follows the division of these nerves; and the first gentlemen affirm, that horses have eaten as usual, and apparently with the same appetite, after they had removed several inches of the pneumogastric nerves; and even continued to eat after the stomach was filled. To these experiments we shall have occasion to refer hereafter. They by no means, however, exhibit that this internal sensation differs in its essence from others.

A difficulty, which the physiologist has always felt, concerns the precise nature of the action of impression. Its seat is clearly in the stomach. This was shown incontestably by a case of fistulous opening into the organ, which fell under the care of Dr. Beaumont, and to which there will be frequent occasion to refer. When the subject of this case was made to fast until his appetite was urgent, it was immediately assuaged by feeding him through the aperture. To the stomach, indeed, all our feelings refer the sensation. It is dependent upon some modification occurring in the very tissue of the viscus; and in the nerves, which, as has been shown, are the sole agents in all phenomena of sensibility. These nerves are spread over the stomach, so that the precise seat of the impression cannot be as accurately defined as in the case of the organs of external sense. Moreover, the nerves of the stomach proceed from two essentially different sources,—the eighth pair, and great sympathetic. The question consequently arises:—on which of these is the impression made? The results of the experiment of cutting the eighth pair in the neck would appear to decide in favour of the former.

As to the proximate or efficient cause of hunger, we cannot expect to arrive at any satisfactory conclusion. It is a sensation; and, like all sensations, inscrutable. Theories, however, as on all obscure topics, have been numerous, and these have generally been of a mechanical or a chemical nature. Some have attributed it to the mechanical friction of the parietes of the stomach against each other, in consequence of its contraction; in which state, they affirm, the mucous coat is rugous, and its papillæ and follicles prominent. It is manifest, however, from the structure of the organ, that no such friction can take place. Yet this view was embraced by Haller.[5] Dr. Fletcher[6] ascribes it to a kind of permanent though partial contraction of the muscular fibres of the stomach;—"not that alternate general contraction and relaxation,

[1] Recherches Physiologiques et Chimiques pour servir à l'Histoire de la Digestion, Paris, 1825.

[2] Edinb. Med. and Surg. Journal, April, 1839, and art. Par Vagum, in Cyclop. of Anat. and Physiol., Pt. xxviii., p. 899, Lond., April, 1847.

[3] Untersuchungen zur Physiologie und Pathologie, Bonn, 1835–6.

[4] Traité de Physiologie, ii. 342, Paris, 1850.

[5] Element. Physiol., lib. xix., sect. 2, § 12, Bern., 1764.

[6] Rudiments of Physiology, Part iii., by Dr. Lewins, p. 73, Edinb., 1837.

which produces a sensible motion of this organ, nor that permanent general contraction, which would serve to diminish its cavity, but that kind of permanent contraction, which takes place in certain fibres alone, and perhaps through a part of their length only, and by which these fibres are, as it were, drawn away from the others, or, in other words, a minor degree of cramp." Others, again, have accounted for the sensation by the action of the gastric juice, which is supposed to have a tendency to irritate the internal membrane. In proof of this, they refer to a case, mentioned by Mr. Hunter, in which the mucous membrane, in a man who died of fasting, was found corroded. The gastric juice is, however, incapable of eroding living animal matter; and the numerous cases, which have occurred since that of Hunter, have shown, that the corrosion and perforation, which we meet with on dissection, are to be referred to an action after death, and must, consequently, be totally unconnected with the sensation felt during life. We have, indeed, no reason for believing that the gastric juice can ever attain a state of acridity, and affect physically the surface by which it is secreted. It has been remarked, that it is a law of the animal economy, that no secretion acts upon the part over which it is destined to pass, provided such part be in a healthy condition. Yet Sömmering[1] ascribes the pain from long-continued fasting to the action of the gastric juice; and Dr. Wilson Philip[2] is manifestly induced to believe that its influence on the stomach is, in some mode or other, productive of the sensation: his remarks, however, tend simply to show,—what we have so many opportunities for observing, that the sensation can be postponed by exciting vomiting, or inducing, for the time, a morbid condition of the stomach. The unanswerable objection, however, to all these views is the fact—repeatedly proved by Dr. Beaumont,[3] and which the author had an opportunity of observing—that, in the fasting state there is little or no gastric juice in the cavity of the stomach. Dr. Beaumont thinks, that the sensation of hunger is produced by distension of the vessels, that secrete the solvent; but such distension, if it exist—which is by no means proved—must itself be consecutive on the nervous condition that engenders the sensation: the efficient cause of such condition has still to be explained. Bichat, again, attributed it to the lassitude or fatigue of the stomach, occasioned by the contraction of its muscular coat when continued beyond a certain time. In answer to this, it may be remarked, that if any thing impedes the nutrition of the body, hunger continues, although the stomach may be distended. This happens in cases of scirrhous pylorus, where the nutritive mass cannot pass into the small intestine, to be subjected to the action of the chyliferous vessels, and the losses of the body cannot, therefore, be repaired;—facts which would seem to show, that hunger is a sensation excited in the stomach by sympathy with the wants of the constitution; and that it is immediately produced by some inappreciable alteration in the condition of the nerves of the organ. It appears, from the experiments

[1] De Corp. Human. Fabric. tom. vi., Traject. ad Mœnum, 1794–1801.

[2] Experimental Inquiry into the Laws of the Vital Functions, 2d edit., Lond., 1818.

[3] Experiments and Observations on the Gastric Juice, and the Physiology of Digestion, p. 57, Plattsburg, 1833.

of M. Magendie,[1] that when the cerebrum and a great part of the cerebellum were removed in ducks, the instinct of seeking food was lost in every instance, and the instinct of deglutition in many: food, however, introduced into the stomach, was found to be digested.

b. *Prehension of Food.*

The arms and mouth have been described as organs of prehension. It is scarcely necessary to say, that the hands seize the food and convey it to the mouth under ordinary circumstances; but there are cases in which the mouth is the sole or chief organ of prehension. Most animals are compelled to use the mouth only. When the food is conveyed to it by the hands, it must open to receive it. The mode in which this is effected has given rise to controversy; and, strange to say, is not yet considered determined. Whilst some physiologists have asserted, that the lower jaw alone acts in opening the mouth moderately; others have affirmed, that both the jaws separate a little;—the lower, however, moving five or six times as much as the upper. That the latter is the correct view can be proved by positive experiment. If, when the mouth is closed, we place the flat side of the blade of a knife against the teeth of both jaws; and, holding the knife immovably, separate the jaws; we find, that both jaws move on the blade; but the lower to a much greater extent than the upper. Now, as the upper jaw is fixed immovably to the head, the whole head must, of necessity, participate in this movement; and the question arises, what are the agents that produce it? Some attribute it to a slight action of the extensor muscles of the head; and affirm, that whilst the depressors of the lower jaw carry it downwards, the extensors of the head draw the head slightly backwards, and thus raise the upper jaw.

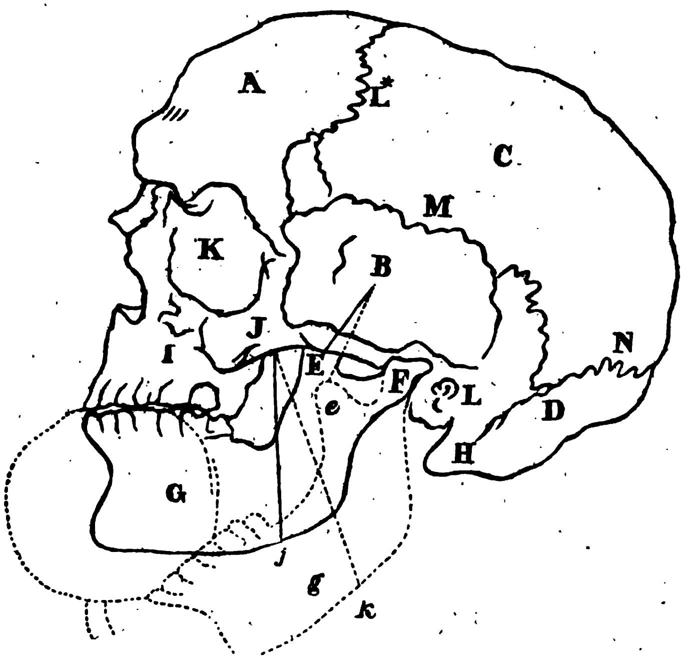
MM. Magendie[2] and Adelon[3] assert, that when the mouth is opened moderately, the upper jaw does not participate; but, that if the motion be "forced" or extensive, it participates slightly. The experiment, however, with the knife, which is adduced by M. Adelon himself, completely overthrows this notion; and shows, that both jaws act, whenever the mouth is slightly opened. M. Magendie agrees with those who consider, that, whenever the upper jaw is raised, it must be by the head being thrown back on the vertebral column; and he properly remarks, that where there is a physical impediment to the depression of the lower jaw, the mouth must be opened solely by the retroversion of the head on the spine. M. Ferrein[4] conceived, that the motion of the upper jaw is occasioned by the action of the stylo-hyoideus muscle, and the posterior belly of the digastricus; and he affirms, that whilst the anterior fasciculus or belly of the digastricus depresses the lower jaw; the posterior belly with the stylo-hyoideus carries the head backwards, and, with it, the upper jaw. The attachments, however, of these muscles sufficiently show, that they cannot be the agents: the mastoid process, to which the posterior belly of the digastric muscle is attached, is near the articulation of the head with the atlas; whilst the styloid process, to which

[1] Précis, &c., ii. 168. [2] Op. citat., ii. 43. [3] Op. citat., ii. 408.
[4] Mémoir. de l'Acad. des Sciences pour 1744.

the stylo-hyoideus is attached, is anterior to the articulation; and its effect ought to be to depress the upper jaw. The view of Professor Chaussier is the most probable. He ascribes the slight elevation of the upper jaw to the mechanical arrangement of the joint of the lower. The temporo-maxillary articulation is not formed by a single condyle, but by two, which are so disposed, that the lower cannot roll downwards during the depression of the lower jaw without causing the upper condyle to roll upwards, and, consequently, to elevate slightly the upper jaw. Under ordinary circumstances, then, the jaws cannot be at all separated without both participating; but if we determine to fix the upper jaw we can make the lower the sole agent in the movement.

As soon as the food is introduced into the mouth, the jaws are closed to retain it, and subject it to mastication. Frequently, however, they assist in the act of prehension, as when we bite a fruit, to separate a portion from it;—the incisor teeth acting, in such case, like scissors. This is chiefly produced by the contraction of the muscles that raise the lower jaw; and it is probable, that the action of the stylo-hyoideus

Fig. 247.



Action of the Lower Jaw in Prehension.

A. Frontal bone. B. Temporal. C. Parietal. D. Occipital. E. Coronoid process of the lower jaw, to which the temporal muscle is attached. F. Condyloid process or head of the lower jaw. G. Lower jaw. H. Mastoid process. I. Upper jaw. J. Cheek bone. K. Orbit. L. Meatus auditorius externus. L*. Coronal suture. M. Squamous suture. N. Lambdoidal suture. g. Lower jaw depressed.

is concerned in the movement; drawing the head and upper jaw with it downwards and forwards. The levator muscles of the jaw act here with

great disadvantage;—the lower jaw representing a lever of the third kind; the fulcrum being in the joint; the power at the insertion of the levator muscles; and the resistance in the substance between the teeth. The arm of the resistance is, consequently, the whole length of the lever; and we can understand why we are capable of developing so much more force, when the resistance is placed between the molares; and why old people,—who have become toothless, and are, consequently, constrained to bite with the anterior part of the jaws,—the only portion that admits of contact,—cannot bite with any degree of strength.

The size of the body, put between the incisor teeth, influences the degree of force that can be brought to bear upon it. When small the force can be much greater, as the levator muscles are inserted perpendicularly to the lever to be moved, and the whole of their power is advantageously exerted; but if the body be so large, that it can scarcely be received into the mouth, and be resisting withal, the incisors can scarcely penetrate it;—the insertion of the levator muscles into the jaw being rendered very oblique; and the greater part of the force they develope consequently lost. This will be readily seen by Figure 247. When the mouth is closed, or nearly so, the masseter, and temporal muscles represented respectively by the lines B E and J *j*, are inserted nearer the perpendicular; but when the lower jaw is depressed, so that the situation of these muscles is represented by the dotted lines B *e* and J *k*, the direction in which the muscles act will be more oblique, and, therefore, more disadvantageous. When the muscles of the jaws are incapable, of themselves, of separating the substance, as in the case of the apple, the assistance of the muscles of the hand is invoked; whilst the muscles on the posterior part of the neck, which are inserted into the head, draw it backwards; and, by these combined efforts, the substance is forcibly divided.

c. *Oral or Buccal Digestion.*

The changes, effected upon the food in the mouth, are important preliminaries to the function that has to be executed in the stomach and duodenum. As soon as it enters the cavity, it is subjected to the action of the organ of taste; and its sapid qualities are appreciated. By its stay there, it also acquires nearly the temperature of the cavity. This is, however, a change of little moment, unless the food is so hot, that it would injure the stomach, if passed rapidly into it. Under such circumstances, it is tossed about in the mouth, until it has parted with its caloric to various portions of the parietes of the cavity; and then, if in a fit state for the action of deglutition, it is transmitted along the œsophagus; but the most important parts of oral digestion are the movements of mastication and insalivation by which solid food is comminuted, and imbued with the secretions poured into the interior of the mouth, and which we have shown to be of a very compound character.

Under the sense of taste, the influence of the agreeable or disagreeable character of the food upon the digestive function was expatiated upon. It is unnecessary, therefore, to do more than allude to the subject here. We find that whilst a luscious aliment excites to prolonged mastication, and the salivary glands to augmented secretion, the mas-

ticatory and salivary organs, by dividing and moistening the food, permit the organs of gustation to enjoy the savour by successive applications.

When the food is received into the mouth, if it be sufficiently soft, it is commonly swallowed immediately; unless the flavour is delicious, when it is detained. If solid, and, especially, if of any size or density, it is divided into separate portions, or chewed,—the action constituting *mastication.* If the consistence of the substance be moderate, the tongue, by being pressed strongly against the bony palate, is sufficient to effect this division; bruising it, and at the same time, expressing its fluid portions. If the consistence be greater, the action of the jaws and teeth is required. For this purpose, the lower jaw is successively depressed and elevated by the action of its depressors and levators; and the horizontal or grinding motion is produced at pleasure by the action of the pterygoids. Whilst these muscles are acting, the tongue and cheeks are incessantly moving, so as to convey the food between the teeth, and insure its comminution. Mastication is chiefly effected by the molares. There is advantage in using them, independently of their form, in consequence of the arm of the resistance being much shortened, as has already been shown.

The teeth are well adapted for the service they have to perform. The incisors, as their name imports, are used for cutting; hence their coronæ come to an edge; the canine teeth penetrate and lacerate, and their coronæ are acuminated; whilst the molares bruise and grind, and their touching surfaces are tuberous. The first, having usually no great effort to sustain, are placed at the extremity of the lever; the latter, for opposite reasons, are nearest the fulcrum. To preclude displacement by the efforts they have occasionally to sustain, they are firmly fixed in the alveoli or sockets; and, as the roots are conical, and the alveoli accurately embrace them, the force, as in the case of the wedge, is transmitted in all directions, instead of bearing altogether upon the jaw, which it would do, were the fangs cylindrical. The molar teeth, having the greatest efforts to sustain, are furnished with several roots; or with one that is extremely large.

The gums add materially to the solidity of the junction of the teeth with the jaws. They are themselves formed of highly resisting materials, so as to withstand the pressure of hard and irregular substances. Whenever they become spongy, and fall away from the teeth, the latter become loose; and are frequently obliged to be extracted, in consequence of the loose tooth acting as an extraneous body, and inflaming the lining membrane of the alveolus. The arrangement of the jaw is well adapted to the function; the lower jaw passing behind the upper at its anterior part; but coming in close contact at the sides, where mastication is chiefly effected.

During the whole time that mastication is going on, the mouth is closed;—anteriorly, by the lips and teeth, which prevent the food from falling out of the cavity; and posteriorly by the velum palati, the anterior surface of which is applied to the base of the tongue. At the same time, the food is undergoing *insalivation* or admixture with the various fluids poured into the mouth, and particularly with the saliva,

the secretion of which is augmented, not only by the presence of food, but even by the sight of it, especially if the food be desirable;—giving rise to what is called "mouth-watering." It is probable, that, independently of mental association, the action of the secretory organs is increased by the agitation of the organs themselves during the masticatory movements. It has, indeed, been asserted, that the parotid glands are so situate, as regards the jaws, that the movement of the lower jaw presses upon them, and forces out the saliva; but MM. Bordeu and J. Cloquet have demonstrated, anatomically and by experiment, that this is not the case.[1]

It has been supposed by some, that admixture with saliva communicates to the food its first degree of animalization; or in other words, its first approximation to the substance of the animal it has to nourish. Such are the opinions of Professor S. Jackson[2] and M. Voisin.[3] The former asserts, that he has ascertained positively, that the saliva exerts a very energetic operation on the food, separating, by its solvent properties, some of its constituent principles, and performing a species of digestion. MM. Tiedemann and Gmelin, too, think that the water, and the carbonates and acetates of potassa and soda, and the chlorides of potassium and sodium, of the saliva, contribute to soften and dissolve the food; whilst the nitrogenized materials, the salivary and albuminous matters, communicate to it a first degree of animalization. It is more probable, however, that the great use of mastication and insalivation is to give the food the necessary consistence, in order that the stomach and small intestine may exert their action upon it in the most favourable manner; and that, consequently, the changes effected upon it in the mouth, are chiefly of a mechanical character. In the case of many substances—as sugar, salt, &c.,—a true solution takes place in the saliva; and this probably happens to sapid bodies in general;—the particles being separated by imbibing the fluid. Krimer,[4] of Leipzig, held in his mouth a piece of ham, weighing a drachm, for three hours. At the expiration of this time, the ham was white on its surface, and had increased in weight twelve grains. Krimer, it may be remarked, believes, that the tears assist in digestion, and that they flow constantly by the posterior nares into the stomach. It would seem, too, that an important action of the saliva is the conversion of starch into dextrin or grape sugar. From one drachm of starch, Dr. Wright[5] obtained in twelve hours, at a temperature of 98°, by admixture with saliva, thirty-one grains of sugar. This probably takes place by the action of some nitrogenized secretion, like pepsin in stomachal digestion. It has been affirmed, indeed, on the strength of numerous and varied experiments detailed before the French Academy of Sciences,[6] by MM. Bernard de Villefranche and Barreswil, that in the gastric juice, pancreatic fluid, and saliva, an organic principle exists, which is common to them all; and that it is the nature of the chemical reaction associated with it, which alone determines their power of digesting the different aliment-

[1] Adelon, op. cit., ii. 418.
[2] Principles of Medicine, p. 354, Philad., 1832.
[3] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.
[4] Versuch einer Physiologie des Blutes, Leipz., 1820.
[5] Lond. Lancet, 1841-2.
[6] Comptes Rendus, 7 Juillet, 1845.

ary principles. In an alkaline fluid, all three have the power of transforming starch, and do not digest meat; whilst in an acid fluid they dissolve meat, but do not act on starch. Hence, they think, it appears easy to transform these fluids into each other, and to make for example an artificial gastric juice from pancreatic fluid. The action of saliva, however, is said to be less energetic, both on meat and starch, than the pancreatic fluid. For the organic compound in the saliva, M. Mialhe[1] proposes for it the name animal *diastase salivaire.* It would seem, however, from the experiments of MM. Magendie[2] and Bernard,[3] that many substances besides saliva,—as pieces of the mucous membrane of the mouth, bladder, rectum and other parts, various animal and vegetable tissues, and even morbid products effect the transformation of starch into sugar; but that the gastric fluid does not. The part of the saliva, according to M. Bernard, which appears to be most active is that secreted by the small glands and the mucous membrane of the mouth; but it has been properly observed, by Messrs. Kirkes and Paget,[4] that if the influence of saliva in aiding the digestion of farinaceous food be admitted, we have yet to seek for the corresponding purpose served by the saliva of the carnivora, which consume no such food; and on this point we possess at present no information.

It is probable, however, that the main action of saliva is to soften the food; for when substances are well mixed with water, they are retained in the mouth for a short time only; and, consequently, in an amylaceous solution there is no opportunity for change to be effected. Experiments, instituted by M. Lassaigne,[5] by a committee of the Institute, and by M. Bernard[6] show, that when the food is dry a considerable admixture of saliva takes place, whilst if it be so softened, that mastication is not needed, it absorbs scarcely any. In executing these experiments, the aliment was weighed before giving it to the animal; the œsophagus was cut across; and the aliment, after having been chewed and insalivated, was inserted through the wound in the neck. The difference in weight indicated the quantity of saliva that had been added to it.

According to Professor Berard,[7] these experiments teach us: *First.* That dry forage absorbs about four or five times its weight of saliva and mucus. *Secondly.* That dry feculaceous articles (oats, starch and barley meal) absorb a little more than their weight. *Thirdly.* That green forage (green leaves and stalks of barley) absorb a little less than half their weight; and *fourthly;* that moist feculaceous articles (starch and bran) to which sufficient water has been added for the food to be swallowed without previous mastication, do not sensibly absorb any.

Both mastication and insalivation are of moment, in order that digestion shall be accomplished in perfection; and, accordingly, they who

[1] Lancette Française, Avril, 1845; and Ranking's Abstract, vol. i. Part. ii., Amer. edit., p. 270, New York, 1846.
[2] Comptes Rendus, 1847, p. 117.
[3] Canstatt und Eisenmann, Jahresbericht über die Fortschritte in der Biologie, im Jahre, 1847, s. 117.
[4] Manual of Physiology, Amer. edit., p. 162, Philad., 1849.
[5] Journal de Chimie Médicale, p. 472, Paris, 1845.
[6] Archives Générales de Médecine, 4e série, tom. xiii. p. 1.
[7] Cours de Physiologie, p. 721, Paris, 1848.

swallow food without due mastication, or waste the saliva by constant and profuse spitting, are more liable to attacks of dyspepsia, or imperfect digestion. It is proper, however, to add, that Dr. Budge,[1] on extirpating the salivary glands in animals, did not find that they sustained the smallest apparent injury; whence he conjectures, that certain glands can act as succedanea to others, and that in the removal of the salivary glands the pancreas supplies perhaps the fluid usually secreted by the other.

A table given by Dr. Robert Dundas Thomson[2] as the results of experiments on two cows, signally exhibits the beneficial effects of a proper grinding of the food. The cows were fed on entire barley and malt steeped in hot water. They were then fed on crushed barley and malt prepared in the same manner. The influence of the finer division of the grain in increasing the quantity of milk is strikingly shown.

	Brown Cow. Milk in periods of five days.	White Cow. Milk in periods of five days.
Entire barley and grass,	111½ lbs.	106 lbs.
	97½ "	94 "
Entire malt and grass,	96 "	98 "
	95 "	104 "
Crushed barley, grass and hay,	115½ "	109½ "
	105 "	109½ "
	110 "	110 "
Crushed malt and hay,	97 "	106½ "
	96 "	107½ "
	98 "	111½ "

The table exhibits, that with the entire barley, the milk diminished during the second five days of the experiment, whilst with the crushed barley it had a tendency to increase during each succeeding period.

The degree of resistance, and sapidity of the food, apprise us when mastication and insalivation have been sufficiently exerted. When this is the case it is subjected to the next of the digestive processes. Some physiologists have affirmed, that the uvula is the organ which judges when the food is adapted for deglutition. M. Adelon, whose views are generally worthy of great favour and attention, asserts, "that it judges by its mode of sensibility, of the degree in which the aliment has been prepared in the mouth; of the extent to which it has been chewed, impregnated with saliva, and reduced to paste; and, according to the impression it receives, it excites, sympathetically, the action of all those parts; directs the convulsive contraction of the muscles that raise the pharynx, even keeps the stomach on the alert, and disposes it to receive favourably or to reject the food passing to it." Such a function would be anomalous. It is, indeed, impossible for us to conceive, how so insignificant an organ could be possessed of those elevated attributes. Observation, also, proves, that the notion is the offspring of fancy. M. Magendie[3] asserts, that he has known several persons who had entirely lost the uvula, either by venereal ulceration or by ex-

[1] Medicinische Zeitung, May 4, 1842; cited in British and For. Med. Rev., July, 1842, p. 221.
[2] Experimental Researches on the Food of Animals, Amer. edit., New York, 1846.
[3] Op. cit., ii. 58.

cision, and yet he never remarked that their mastication experienced the slightest modification, or that they swallowed inopportunely. Our experience corresponds with that of M. Magendie. We know of more than one individual in whom there is not the slightest vestige of uvula, yet they taste, chew, and swallow like other persons.

d. *Deglutition.*

The act of swallowing, although executed with extreme rapidity, and apparently simple, is the most complicated of the digestive operations, and requires the action of mouth, pharynx and œsophagus. It has been well analyzed by M. Magendie,—first of all in a thesis, maintained at the *Ecole de Médecine* of Paris, in 1808, and subsequently, in his *Précis Elémentaire de Physiologie.*[1] To facilitate its study, he divides it into three stages. In the *first*, the food passes from the mouth into the pharynx; in the *second*, it clears the apertures of the glottis and nasal fossæ, and attains the œsophagus; and, in the *third*, it clears the œsophagus and enters the stomach.

1. When the food has been sufficiently masticated and imbued with saliva, it is collected by the action of the cheeks and tongue upon the upper surface of the last organ;—the mass being more or less rounded, and hence usually termed *alimentary bolus.* Mastication now stops; the tongue is raised and applied against the bony palate in succession from the tip to the root, and the alimentary bolus, having no other way of escaping from the force pressing it, is directed towards the pharynx. Previous to this, the pendulous veil of the palate had been applied to the base of the tongue. The bolus now raises it to the horizontal position: the circumflexus palati muscles render the velum tense, so that the food cannot pass into the nasal fossæ; and the muscles that constitute the pillars of the fauces—palato-pharyngei and glosso-staphylini—contribute to this effect. By this combination of results, the food is impelled into the pharynx. The muscles, which, by their action, apply the tongue to the roof of the mouth and to the velum palati, are the proper muscles of the organ, aided by the mylo-hyoidei. In this first stage of deglutition, the motions are voluntary, except those of the velum palati. The process is not executed with rapidity, and is easily intelligible. Such is not the case with the second stage. The actions in it are complicated, and executed with so much celerity, that they have been regarded as a kind of convulsion.

2. The distance, over which the bolus has to travel, in the second stage, is trivial; the rapidity of its course is owing to the larynx or superior aperture of the windpipe, which opens into the pharynx, having to be cleared instantaneously, otherwise respiration might be arrested, and serious effects ensue. The mode, in which the second stage is accomplished, is as follows. As soon as the alimentary bolus comes in contact with the pharynx all is activity; the pharynx contracts, embraces, and presses the bolus; and the velum pendulum, drawn down by the palato-pharyngei and glosso-staphylini muscles, fulfils a similar office. At the same time, the genio-glossus, by applying the

[1] Edit. cit., ii. 63.

tongue to the palate, from the tip to the root, raises the os hyoides, the larynx, and, with it, the anterior paries of the pharynx. The same effect is directly induced by the contraction of the mylo-hyoidei, and genio-hyoidei muscles; which, instead of acting as depressors of the lower jaw, as they do during mastication, take the jaw as their fixed point, and are levators of the os hyoides. The larynx is thus elevated, carried forwards, and meets the bolus to render its passage over the aperture of the larynx shorter, and, therefore, more speedy. To aid this effect,—when we make great efforts to swallow, the head is inclined forwards on the thorax. Whilst the os hyoides and the larynx are raised, they approach each other,—the upper margin of the thyroid cartilage passing behind the body of the hyoid bone: the epiglottic gland is pushed backward, and the epiglottis is depressed, and inclined backwards and downwards, so as to cover the entrance to the larynx. The cricoid cartilage executes a rotatory motion on the inferior cornua of the thyroid cartilage, which occasions the entrance of the larynx to become oblique from above to below, and, of course, from before to behind. The bolus thus glides over its surface; and, forced on by the veil of the palate, and by the constrictors of the pharynx, reaches the œsophagus.

At one time, it was universally believed, that the epiglottis is the sole agent in preventing substances from passing into the larynx. The experiments of M. Magendie[1] have, however, demonstrated, that this is the combined effect of the motions of the larynx just described, and of the muscles, whose office it is to close the glottis; so that, if the laryngeal and recurrent nerves be divided in an animal, and the epiglottis be left in a state of integrity, deglutition is rendered extremely difficult;—the principal cause, that prevented the introduction of aliments into the glottis, having been removed by the section. M. Magendie, and MM. Trousseau and Belloc[2] refer to cases of individuals, who were totally devoid of epiglottis, and yet swallowed without any difficulty,[3] and Magendie remarks, that if, in laryngeal phthisis with destruction of the epiglottis, deglutition be laboriously and imperfectly accomplished, it is owing to the carious condition of the arytenoid cartilages, and to the lips of the glottis being so much ulcerated as not to be able to close the glottis accurately. Whilst the bolus, then, is passing over the top of the larynx, respiration must be momentarily suspended, owing to closure of the glottis; and if, from distraction of any kind, we attempt to speak, laugh, or breathe, at the moment of deglutition, the glottis opens, the food enters, and cough is excited, which is not appeased, until the cause is removed. This is what is called, in common language, "the food going the wrong way." As soon as the bolus has cleared the glottis, the larynx descends, the epiglottis rises, and the glottis opens to give passage to the air. This is owing to the relaxation of the muscles that had previously raised the larynx and

[1] Mémoire sur l'Usage de l'Epiglotte dans la Deglutition, Paris, 1813; and Précis, &c., i. 67.

[2] A Practical Treatise on Laryngeal Phthisis, &c. &c.; Dr. Warder's translation, p. 84, in Dunglison's American Medical Library, Philad., 1839.

[3] A similar case is given by Targioni, in which neither deglutition nor speech was impaired; Morgagni, xxviii. 13.

closed the glottis. M. Chaussier thinks, that the sterno-hyoidei muscles now act, and aid in producing the descent of the parts.[1] The author had an excellent opportunity for noticing the laryngeal phenomena of deglutition in a man, who had cut his throat, and in whom a fistulous opening remained, which permitted the inferior ligaments of the larynx to be seen distinctly. The glottis was observed to be firmly closed.[2] M. Longet,[3] who has made experiments connected with this subject on animals, is disposed to think, that the displacements of the base of the tongue and epiglottis are the two most important conditions, and that the closed glottis is only the last obstacle set up against the passage of food into the larynx; but he evidently assigns too much importance to the epiglottis.

The velum pendulum, then, protects the posterior nares and the orifices of the Eustachian tube from the entrance of the food; and the epiglottis, the elevation of the larynx, with the contraction of the muscles that close the glottis, are the great agents in preventing it from passing into the larynx. The whole of this second stage consists of rapid movements, of an entirely involuntary character, which, according to Bellingeri,[4] are under the presidency of the palatine filaments of the fifth pair; but these filaments are sensory; the motor filaments being probably derived from the pneumogastric; or, according to M. Longet, from the spinal.[5]

3. In the third stage, the pharynx, by its contraction, forces the alimentary bolus into the œsophagus, so as to somewhat dilate the upper part of the organ. The upper circular fibres are thus excited to action, and force the food onward. In this way, by the successive contraction of the circular fibres, it reaches the stomach. In the upper part of the œsophagus, the relaxation of the circular fibres speedily follows their contraction; but this is not the case in the lowest third, the circular fibres remaining contracted, for some time after the entrance of the bolus into the stomach,—probably to prevent its return into the œsophagus. The passage of the bolus along the œsophagus is by no means rapid. M. Magendie[6] affirms, that he was struck, in the prosecution of his experiments, with the slowness of its progression. At times, it was two or three minutes before reaching the stomach; at others, it stopped repeatedly, and for some time. Occasionally, it even ascended from the inferior extremity of the œsophagus towards the neck, and subsequently descended again. When any obstacle existed to its entrance into the stomach, this movement was repeated a number of times, before the food was rejected. Every one must have felt the slowness of the progression of the food through the œsophagus when a rather larger morsel than usual has been swallowed. If it stops, we are in the habit of aiding its progress by drinking some fluid, or by swallowing a piece of bread. Occasionally, however, the probang is necessary to propel it. The pain produced in these cases, according to M. Magendie, is owing

[1] Adelon, op. citat., ii. 424.
[2] Dunglison's American Medical Intelligencer, Oct., 1841, p. 73.
[3] L'Examinateur Médical, 17 Oct., 1841; and Brit. and For. Med. Rev., Jan., 1842, p. 228.
[4] Dissert. Inaugural. Turin, 1823; noticed in Edinb. Med. and Surg. Journ. for July, 1834.
[5] Traité de Physiologie, ii. 337, Paris, 1850.
[6] Op. citat., ii. 69.

to the distension of the nervous filaments, that surround the pectoral portion of the canal. In the case of a female, labouring under a disease which permitted the interior of the stomach to be seen, M. Hallé noticed, that whenever a portion of food passed into the stomach, a sort of ring or *bourrelet* was formed at the cardiac orifice, owing to the mucous membrane of the œsophagus being forced into the stomach by the contraction of its circular fibres.[1] The mucous fluid pressed out from the different follicles, by the passage of the bolus, materially facilitates its progress.

Notwithstanding the facility with which deglutition is accomplished, almost every part of it is uninfluenced by volition, being dependent upon organization, and exerted instinctively. If the alimentary matter contained in the mouth be not sufficiently masticated; or if it has not the shape, consistence, and dimensions, it ought to possess; or if the ordinary movements, that precede mastication, have not been executed,—whatever effort we may make, deglutition is impracticable. We constantly meet with persons who are unable to swallow the smallest pill; and yet can swallow a much larger mass, if certain preliminary motions be executed, which, in the case of the pill, are inadmissible, in consequence of its being usually of a nauseous character. It appears, that the involuntary parts of the function are excited by the stimulation of the aliment; for, if we attempt to swallow the saliva several times in succession, we find after a time, that the act is impracticable, owing to the deficiency of saliva. Every one must have experienced the difficulty of deglutition, when the mouth and fauces were not duly moistened by their secretions. The involuntary part of deglutition is under the control of the reflex system of nerves. An impression is made by the alimentary matters upon the excitor or afferent nerves, which impression is conveyed to the gray matter of the spinal cord, and in the invertebrata to ganglia corresponding to it; whence it is reflected to the muscular fibres that have to be thrown into contraction. The portion of the spinal cord, which serves as a centre for the reception of the impression, and the point of departure for the motor influence, is the medulla oblongata; and the experiments of Dr. John Reid[2] lead to the inference, that the glosso-pharyngeal, which is chiefly distributed to the mucous surface of the tongue and fauces, is the excitor nerve; the pharyngeal branches of the pneumogastric, the motors. It would seem, however, that these nerves do not alone possess the function; for after they have been divided, the animal is still capable of imperfect deglutition. The associate excitor or afferent nerves, Dr. Reid concludes to be—the branches of the fifth pair, that are distributed to the fauces, and probably also those of the superior laryngeal distributed to the pharynx:—the associate motor or efferent nerves being branches of the hypoglossal, that are distributed to the muscles of the tongue, and to the sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles; filaments of the inferior laryngeal that ramify on the larynx; some of the branches of the fifth pair that supply the levator muscles of the lower jaw; the branches of the portio dura that

[1] Op. cit., ii. 70.

[2] Edinb. Med. and Surg. Journ., vol. xlix.

ramify upon the digastric and stylo-hyoid muscles, and upon the muscles of the lower part of the face; and probably some of the branches of the cervical plexus, which unite themselves to the descendens noni. It must be admitted, however, that this part of the physiology of deglutition is obscure.[1]

Some individuals are capable of swallowing air; and, according to M. Magendie,[2] it is an art that can be attained by a little practice. In the stomach, the air acquires the temperature of the viscus, becomes rarefied, and distends the organ; exciting, in some, a feeling of burning heat; in others, an inclination to vomit, or acute pain. He thinks it probable, that its chemical composition undergoes change; but, on this point, nothing certain is known. The time of its stay in the stomach is variable. Commonly, it ascends into the œsophagus, and makes its exit through the mouth or nostrils. At other times, it passes through the pylorus, and diffuses itself through the whole of the intestinal canal, as far as the anus,—distending the abdominal cavity, and simulating tympanites. M. Magendie refers to the case of a young conscript, who feigned the disease in this manner.

e. *Chymification.*

When the food has experienced changes impressed upon it by the preceding process, it reaches the cavity of the stomach, where it is retained for several hours, and undergoes another portion of the digestive action, being converted into a pultaceous mass, to which the term *chyme* has been applied; whilst the process has been called *chymification.* It does not seem, that all physiologists have employed these terms in this signification; some have confounded *chyle* with *chyme;* and *chylification* with *chymification.* The former of these processes is distinctly an intestinal act: the latter is exclusively gastric.

The aliment, as it is sent down by repeated efforts of deglutition, descends into the splenic portion of the stomach without difficulty, as regards the first mouthfuls. The stomach is but little compressed by the surrounding viscera, and its parietes readily separate to receive the food; but when it is taken in considerable quantity, the distension gradually becomes more difficult, owing to the compression of the viscera and the distension of the abdominal parietes. The accumulation takes place chiefly in the splenic and middle portions. Dr. Beaumont[3] observed, that when a piece of food was received into the stomach, the rugæ of the latter gently closed upon it; and if it were sufficiently fluid, gradually diffused it through the cavity of the organ, but entirely excluded more whilst the action continued. The contraction ceasing, another quantity of food was received in the same manner. It was found, in the subject of his experiments, that when the valvular portion of the stomach, situate at the fistulous aperture, was depressed, and solid food introduced, either in large pieces or finely divided, the same gentle contraction or grasping motion took place, and continued for fifty or eighty seconds, and it would not allow of another quantity, until

[1] Longet, Traité de Physiologie, ii. 334, 337, Paris, 1850.
[2] Carpenter, Human Physiology, ii. 146. [3] Experiments, &c., on the Gastric Juice, p. 110.

that period had elapsed: the valve could then be depressed, and more food put in. When the man was so placed, that the cardia could be seen, and was permitted to swallow a mouthful of food, the same contraction of the stomach and grasping of the bolus were invariably observed to commence at the œsophageal ring. Hence, when food is swallowed too rapidly, irregular contractions of the muscular fibres of the œsophagus and stomach are prodnced; the vermicular motions of the rugæ are disturbed, and the regular process of digestion is interrupted.

Whilst the stomach is undergoing distension by food, it experiences changes in its size, situation, and connexion with the neighbouring organs. The dilatation does not affect its three coats equally. The two laminæ of the peritoneal coat separate, and permit the stomach to pass farther between them. The muscular coat experiences a true distension; its fibres lengthen, but still so as to preserve the particular shape of the organ; whilst the mucous coat yields, in those parts especially where the rugæ are numerous; that is, along the great curvature and splenic portion. In place, too, of being flattened at its anterior and posterior surfaces, and occupying only the epigastrium, and a part of the left hypochondrium, it assumes a rounded figure. Its great *cul-de-sac* descends into the left hypochondre and almost fills it, and the greater curvature descends towards the umbilicus, especially on the left side. The pylorus preserves its position and connexion with the surrounding parts;—being fixed down by a fold of the peritoneum. It is chiefly forwards, upwards, and to the left side, that the dilatation occurs. The posterior surface cannot dilate on account of the resistance of the vertebral column, and of a ligamentous formation which prevents the stomach from pressing on the great vessels behind it. Its cardiac and pyloric portions are also fixed; so that when it is undergoing distension, a movement of rotation takes place, by which the great curvature is directed slightly forwards; the posterior surface inclined downwards, and the superior upwards. A wound received in the epigastric region, will, consequently, penetrate the stomach in a very different part, according as the viscus may be, at the time, full or empty.

The dilatation of the organ produces changes in the condition of the abdomen and its viscera. The total size of the abdominal cavity is augmented; the belly becomes prominent; and the abdominal viscera are compressed,—sometimes so much as to excite a desire to evacuate the contents of the bladder or rectum. The diaphragm is crowded towards the thorax, and is depressed with difficulty; so that, not only is ordinary respiration cramped; but speaking and singing become laborious. When the distension of the organ is pushed to an enormous extent, the parietes of the abdomen may be painfully distended, and the respiration really difficult. It is in these cases of over-distension, that an energetic contraction of the œsophagus is necessary; hence the advantage of the strong muscular arrangement at its lower part. In proportion as the food accumulates in the stomach, the sensation of hunger diminishes; and, if we go on swallowing additional portions, it entirely disappears, or is succeeded by nausea and loathing. The quantity, necessary to produce this effect, varies according to the individual,

as well as to the character of the food; a very luscious article sooner cloying than one that is less so. A due supply of liquid with solid aliment also enables us to prolong the repast with satisfaction.

As the stomach, when distended, presses upon the different viscera and upon the abdominal parietes, it is obvious, that it must experience a proportionate reaction. An interesting question consequently arises;—to determine the causes, which oppose the passage of the food back along the œsophagus, as well as through the pylorus. M. Magendie[1] found, in his vivisections, that the lower portion of the œsophagus experiences, continuously, an alternate motion of contraction and relaxation. The contraction begins at the junction of the two upper thirds with the lowest third; and is propagated, with some rapidity, to the termination of the œsophagus in the stomach. Its duration, when once excited, is variable; the average being, at least, half a minute. When thus contracted, it is hard and elastic, like a cord strongly stretched. The relaxation, that succeeds the contraction, occurs suddenly and simultaneously in all the contracted fibres; at times, however, it appears to take place from the upper fibres towards the lower. In the state of relaxation, the œsophagus is remarkably flaccid;—forming a singular contrast with that of contraction. This movement of the œsophagus is, according to M. Magendie,[2] under the dependence of the eighth pair of nerves. When these nerves were divided in an animal, the œsophagus was no longer contracted. Still it was not relaxed. Its fibres, deprived of nervous influence, were shortened with a certain degree of force; and the canal remained in a state intermediate between contraction and relaxation.

The lower part of the œsophagus of the horse, for an extent of eight or ten inches, is not contractile in the manner of muscles. M. Magendie[3] found, when the eighth pair of nerves was irritated, or the parts were exposed to the galvanic stimulus, that no contraction was produced. The œsophagus of that animal is, however, highly elastic; and its lower extremity is kept so strongly closed, that for a long time after death, it is difficult to introduce the finger; and considerable pressure is required to force air into it. M. Magendie considers this arrangement to be the true reason, why horses vomit with such difficulty as to occasionally rupture the stomach by their efforts. The alternate motions of the œsophagus, which we have described, oppose the return of the food from the stomach. The more the organ is distended, the more intense and prolonged is the contraction, and the shorter the relaxation. The contraction commonly coincides with inspiration; the time at which the stomach is, of course, most strongly compressed. The relaxation is synchronous with expiration.

The pylorus prevents the alimentary mass from passing into the duodenum. In living animals, whether the stomach be filled or empty, this aperture is constantly closed by the constriction of its fibrous ring, and the contraction of its circular fibres; and, so accurately is it closed, that, if air be forced into the stomach from the œsophagus, the organ must be distended, and considerable exertion made to overcome the resistance of the pylorus. Yet, if air be forced from the small intes-

[1] Précis, &c., ii. 82. [2] Ibid., ii. 18. [3] Ibid., ii. 19.

tine in the direction of the stomach, the pylorus offers no resistance;—suffering it to enter the organ under the slightest pressure;—a circumstance that accounts for the facility with which bile enters the stomach; especially when there exists inverted action of the duodenum. To the pylorus, however, a more active part has been assigned in the passage of the chyme from the stomach into the intestine. "Nothing in the animal economy," says Dr. Southwood Smith,[1] "is more curious and wonderful than the action of that class of organs of which the pylorus affords a remarkable example. If a portion of undigested food present itself at this door of the stomach, it is not only not permitted to pass, but the door is closed against it with additional firmness; or, in other words, the muscular fibres of the pylorus, instead of relaxing, contract with more than ordinary force. In certain cases, where the digestion is morbidly slow, or where very indigestible food has been taken, the mass is carried to the pylorus before it has been duly acted upon by the gastric juice: then, instead of inducing the pylorus to relax, in order to allow of its transmission to the duodenum, it causes it to contract with so much violence as to produce pain, while the food, thus retained in the stomach longer than natural, disorders the organ: and if digestion cannot ultimately be performed, that disorder goes on increasing until vomiting is excited, by which means the load that oppressed it is expelled. The pylorus is a guardian placed between the first and the second stomach, in order to prevent any substance from passing from the former until it is in a condition to be acted upon by the latter; and so faithfully does this guardian perform its office, that it often, as we have seen, forces the stomach to reject the offending matter by vomiting, rather than allow it to pass in an unfit state; whereas, when chyme, duly prepared, presents itself, it readily opens a passage for it into the duodenum." This view of the functions of the pylorus has antiquity in its favour. It is, indeed, as old as the name, which was given to it in consequence of its being believed to be a faithful porter or janitor, (πυλωρος, "a porter;") but it is doubtless largely hypothetical. We constantly see substances traverse the whole extent of the intestinal canal, without having experienced the slightest change in the stomach. Buttons, half-pence, &c., have made their way through, without difficulty; as well as the tubes and globes, employed in the experiments of Spallanzani, Stevens, and others. There are certain parts of fruits, which are never digested, yet the "janitor" is always accommodating. Castor oil is capable of being wholly converted into chyle; and would be so, if it could be retained in the stomach and small intestines; yet there is no agent, which arrests its onward progress. Still, from these, and other circumstances, M. Broussais[2] has inferred, that there is an internal gastric sense, which exerts an elective agency; detaining, as a general rule, substances that are nutritive; but suffering others to pass.

The presence of food in the stomach after a meal soon excites the organ to action, although no change in the food is perceptible for some time. The mucous membrane becomes more florid, in consequence of

[1] Animal Physiology, Library of Useful Knowledge, p. 41.

[2] Traité de Physiol. appliquée à la Pathologie; translated by Drs. Bell and La Roche, p. 314, Philad., 1832.

the larger afflux of blood; and the different secretions appear to take place in greater abundance; become mixed with the food, and exert an active and important part in the changes it experiences in the stomach. Direct experiment has proved that such augmented secretion actually occurs. If an animal be kept fasting for some time, and then be made to swallow dry food, or even stones, and be deprived of liquid aliment, the substances swallowed will be found,—on killing it some time afterwards,—surrounded by a considerable quantity of fluid. Such is not the case with animals killed after fasting. The stomach then contains no fluid matter. The augmented secretion in the former case must, therefore, be owing to the presence of dry food in the stomach. That it is not simply the fluid passed down by deglutition,—the salivary and mucous secretions, for example,—is proved by the fact, that the same thing occurs when the œsophagus has been tied. Besides, if the stomach of a living animal be opened, and any stimulating substance be applied to its inner surface, a secretion is seen to issue in considerable quantity at the points of contact; and, again, if an animal be made to swallow small pieces of sponge, attached to a thread hanging out of the mouth, by means of which they can be withdrawn, they become filled with the fluids secreted by the stomach, and, on withdrawing them, a sufficient quantity can be obtained for analysis. Such experiments have been repeatedly performed by MM. Reaumur,[1] Spallanzani,[2] and others. In Dr. Beaumont's case[3] the collection of gastric secretion was obtained by inserting an elastic gum tube through the opening: in a short time fluid enough was secreted to flow through the tube. This admixture with the fluids of the mucous membrane of the stomach, and the secretions continually sent down from the mouth by the efforts of deglutition, is the only apparent change witnessed for some time after the reception of solid food. Sooner or later, according to circumstances, the pyloric portion of the organ contracts sending into the splenic portion the food it contains: to the contraction dilatation succeeds; and this alternation of movements goes on during the whole of digestion. After this time chyme only is found in the pyloric portion mixed with a small quantity of unaltered food. This motion of contraction and relaxation has been called *peristole;* and it appears, at first, to be limited to the pyloric portion, but gradually extends to the body and splenic portion, so that, ultimately, the whole stomach participates in it. It consists in an alternate contraction and relaxation of the circular fibres; and the gentle oscillation, thus produced, not only facilitates the admixture of the food with the gastric secretions, but continually exposes fresh portions to their action. The experiments of Bichat satisfied him, that the peristole is more marked, the greater the fulness of the stomach. He made dogs swallow forced-meat balls, in the centre of which he placed cartilage, and found, that when the stomach was greatly charged, the cartilages were pressed out of the balls. This did not happen, when the organ contained a smaller quantity of food.

[1] Mémoir. de l'Acad. pour 1752.
[2] Expér. sur la Digestion, Génève, 1783.
[3] Experiments, &c., on the Gastric Juice, p. 106.

The ordinary course and direction of the revolutions of the food, according to Dr. Beaumont,[1] are as follows:—The bolus, as it enters the cardia, turns to the left; passes the aperture; descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns in the course of the lesser curvature, and makes its appearance again at the aperture, in its descent into the great curvature to perform similar revolutions. That these are the revolutions of the contents of the stomach, he ascertained by identifying particular portions of food; and by the fact, that when the bulb of the thermometer was introduced during chymification, the stem invariably indicated the same movements. Each revolution is completed in from one to three minutes, and the motions are slower at first than when chymification has made considerable progress. In addition to these movements, the stomach is subjected to more or less succussion from the neighbouring organs. At each inspiration it is pressed upon by the diaphragm; and the large arterial trunks in its vicinity, as well as the arteries distributed over it, subject it to constant agitation.

It has been already remarked, that the peristaltic action of the stomach,—and the action extends likewise to the intestines,—is effected by the muscular coat of the organ. It is, however, an involuntary contraction, and appears to be little influenced by the nervous system; continuing, for instance, after the division of the eighth pair of nerves; becoming more active, according to M. Magendie,[2] as animals are more debilitated, and even at death; and persisting after the alimentary canal has been removed from the body. MM. Tiedemann and Gmelin,[3] however, affirm, that by irritating the plexus of the eighth pair of nerves situate around the œsophagus with the point of a scalpel, or touching it with alcohol, the peristole of both stomach and intestines can be constantly excited; and Valentin and Dr. John Reid state, that distinct movements may be excited in the stomach by irritating the pneumogastric. This involuntary function, as well as that exerted by the heart and other involuntary organs, affords us a striking instance of the little nervous influence, which seems to be requisite for carrying on many of those functions that have to be executed independently of volition through the whole course of existence; and which appear to be excited at times, in a reflex manner, by the presence of appropriate excitants;—of food, in the case of the peristaltic action of the stomach; of blood, in that of the heart, &c.; and yet may be carried on in the absence of all nervous influence, as in the cases of the intestinal canal, and the heart, which may contract for a long time after they have been removed from the body. In the intestinal canal, the movements are doubtless influenced by the spinal cord, probably through the sympathetic by means of the fibres which the canal derives from it; but although *influenced* by the spinal cord, they are not dependent upon it for contractility. As Dr. Carpenter has remarked, the canal is enabled to propel its contents by its inherent powers; but—as in other instances—the nervous centres exert a general control over even the

[1] Op. citat., p. 110. [2] Précis Elémentaire, ii. 20.

[3] Die Verdauung, u. s. w. or French edit., Recherches sur la Digestion, Paris, 1827.

organic functions, "doubtless for the purpose of harmonizing them with each other, and with the conditions of the organs of animal life."[1]

The gentle, oscillatory or vermicular motion of the stomach, and the admixture with the fluids, secreted by its internal membrane, as well as by the different follicles, &c., in the supra-diaphragmatic portion of the alimentary canal, are probably the main agents in the digestion operated in the stomach.

Much contrariety of sentiment has existed regarding the precise organs that secrete the fluid which oozes out as soon as food is placed in contact with the mucous coat of the stomach. Whilst some believe it to be exhaled from that membrane; others conceive it to be secreted by the numerous follicles, seated in the membrane as well as in that of the lower portion of the œsophagus; or by what have been termed *gastric glands*. The analogy of many animals, especially of birds, would render the last opinion the most probable. In them we find, in the second stomach, the cardiac or gastric glands largely developed; and it is probable, that they are the great agents of the secretion of the digestive fluid. (See Figs. 228 and 229.) MM. Tiedemann and Gmelin[2] affirm, that the more liquid portion of the gastric fluid is exhaled, and that the thicker, more ropy and mucous portion is secreted by the follicles. Rudolphi[3] assigns it a double origin;—from exhalants, and gastric glands; whilst MM. Leuret and Lassaigne[4] ascribe its formation exclusively to the villi. Dr. Beaumont,[5] who had an excellent opportunity for experimenting on this matter, remarks, that on applying aliment, or any irritant, to the internal coat of the stomach, and observing the effect through a magnifying-glass, innumerable minute, lucid points, and very fine papillæ, could be seen protruding, from which a pure, limpid, colourless, slightly viscid fluid distilled, which was invariably and distinctly acid. On applying the tongue to the mucous coat in its empty, unirritated state, no acid taste could be perceived. Although no apertures were perceptible in the papillæ, even with the assistance of the best microscope that could be obtained, the points, whence the fluid issued, were clearly indicated by the gradual appearance of innumerable very fine, lucid specks, rising through the transparent mucous coat, and seeming to burst, and discharge themselves upon the very points of the papillæ, diffusing a limpid, thin fluid over the whole interior gastric surface.

A like difference of opinion has prevailed regarding the chemical character of the fluids; and this has partly arisen from the difficulty of obtaining them identical. The true fluid secreted by the gastric follicles or mucous membrane can never, of course, be obtained for examination in a state of purity. It must always be mixed not only with the other secretions of the stomach, but with all those transmitted to the organ, by the constant efforts of deglutition. It is, consequently, to this mixed fluid, that the term *gastric juice* has really been applied; although it is more especially appropriated to the particular fluid, presumed to be secreted by the stomach, and to be the great agent in diges-

[1] Human Physiology, p. 151, Lond., 1842. [2] Op. citat.
[3] Grundriss der Physiologie, 2er Band, 2te Abtheilung, s. iii., Berlin, 1828.
[4] Recherches sur la Digestion, Paris, 1825. [5] Op. citat., p. 103.

tion. To the nature of the gastric juice and its effects in the process of digestion, we shall have occasion to recur presently.

It is probably owing to the quantity of fluid secreted by the stomach, that it is so largely supplied with bloodvessels; and that the mucous membrane is more injected, during the presence of food in the organ. Experiments, by Sir Benjamin Brodie[1] and others, would seem to show, that the secretion is under the influence of the eighth pair of nerves. Having administered arsenic to different animals—on some of which he had divided these nerves,—he found, that, whilst the stomachs of those, in which the nerves were entire, contained a large quantity of a thin, mucous fluid; in those, whose nerves were divided, the organ was inflamed and dry. Leuret and Lassaigne,[2] however, affirm, that division of the nerves had no influence on the secretion. But more of this presently.

Before entering into the views of different physiologists on chymification,—in other words, into the theories of digestion,—it will be well to refer to the physical and chemical properties of the *chyme*. Whether the changes in the food be simply physical or chemical, or whether the first stage of animalization be effected within the stomach, will be a topic for future inquiry. Chyme is a soft, homogeneous substance, of grayish colour and acid taste. Such are its most common characters: it varies, however, according to the food taken, as may be observed, by feeding animals on different simple alimentary substances, and killing them during digestion. This difference in its properties accounts for the discrepancy observable in the accounts of writers. The change wrought on the aliments is, doubtless, of a chemical nature; but the new play of affinities is controlled by circumstances inappreciable to us. In the case of a female patient at the hospital *La Charité*, of Paris, who had been gored by a bull, and had a fistulous opening in the stomach, the food, during its conversion into chyme, appeared to have acquired an increase of its gelatin; a greater proportion of chloride of sodium; phosphate of soda and phosphate of lime; and a substance, in appearance, fibrinous.[3]

It has been said, again, that the food becomes decarbonized and more nitrogenized; that the carbon which disappears is removed by the oxygen of the air swallowed with the food, or by that contained in the food itself; and that the nitrogen proceeds from the secretions of the stomach, or predominates simply because the food is decarbonized. M. Adelon[4] has properly remarked, that the fact and the explanation are here equally hypothetical. Generally, the chyme possesses acid properties. MM. de Montègre,[5] Magendie,[6] and Tiedemann and Gmelin,[7] always observed it to be so. Haller[8] and Marcet found it to be neither acid nor alkaline. In the chyme examined by the latter gentleman, he detected albumen, an animal matter, and some salts,

[1] Philos. Trans. for 1814.
[2] Op. citat.
[3] Richerand's Nouveaux Elémens de Physiologie, édit. 13ème, par Bérard, ainé, p. 72, Bruxelles, 1837.
[4] Physiol. de l'Homme, &c., edit. cit., tom. ii.
[5] Expériences sur la Digestion, Paris, 1824.
[6] Op. citat., ii. p. 87.
[7] Op. cit.
[8] Element. Physiol., xix. 1.

differing, however, slightly, according as it proceeded from animal or vegetable food. In the latter case, it afforded four times as much carbon as in the former, but less saline matter; and this consisted of lime and an alkaline chloride. MM. Leuret and Lassaigne[1] analyzed the chyme from the stomach of an epileptic, who died suddenly in a fit, five or six hours after having eaten. It was of a white, slightly-yellowish colour; and strong, disagreeable taste. On analysis, it afforded a free acid,—the lactic; a white, crystalline, slightly saccharine matter, analogous to the sugar of milk; albumen, soluble in water; a yellowish, fatty, acid matter, analogous to rancid butter; an animal matter, soluble in water, having all the properties of casein; and a little chloride of sodium, phosphate of soda, and much phosphate of lime. Dr. Prout[2] affirms, that a quantity of chlorohydric acid is present in the stomach during the process of digestion. He detected it in that of the rabbit, hare, horse, calf, and dog, and in the sour matter ejected by persons labouring under indigestion:—a fact which has been confirmed by Mr. Children. MM. Tiedemann and Gmelin, and Dr. Beaumont,[3] affirm, that the secretion of acid commences, as soon as the stomach receives the stimulus of a foreign body, and that it consists of chlorohydric and acetic acids. The experiments of these gentlemen were not confined to the chymous mass obtained from digestible food. They examined the fluids, secreted by the mucous membrane when indigestible substances were sent into the stomach, and the acid character was equally manifested. These experiments, consequently, remove an objection, made by Dr. Bostock,[4] regarding the detection of the chlorohydric acid by Dr. Prout;—that, as there did not appear to be any evidence of the existence of this acid before the introduction of food into the stomach, it might rather be inferred, that it is, in some way or other, developed during the process of digestion. In all Dr. Beaumont's experiments, the chyme was invariably and distinctly acid.

The principal theories on chymification have been the following:—

1. *Coction*, or *elixation*.—This originated with Hippocrates, and was vaguely used by him to signify the maceration, and maturation experienced by the food in the stomach. The doctrine was embraced by Galen and others, who ascribed to the organ, an *attracting*, *retaining*, *concocting*, and *expelling* quality effected by heat.[5] In proof of this, they affirmed that the heat of the stomach is increased during chymification; that the process is more rapid in the warm, than cold-blooded animal; that it is aided by artificial heat, and continues even after death, if care be taken to keep up the heat of the body; that in the experiments on artificial digestion made by Spallanzani, heat was always necessary, and the greater the degree of heat the more easy and complete the digestion.

It is hardly necessary to say that the heat of the stomach is totally insufficient to excite any coction or ebullition in the physical sense of

[1] Recherches, &c., p. 114.
[2] Philos. Trans. for 1824; and Bridgewater Treatise, on Chemistry, &c., Amer. edit., p. 268, Philad., 1834.
[3] On the Gastric Juice, &c., p. 105.
[4] Physiology, 3d edit., p. 569, Lond., 1836.
[5] Boerhaav. Prælectiones Academ. Not. Adv., § 86, tom. i., Gotting., 1740–1743.

the term, and this applies particularly to the cold-blooded animal, which must digest, if not with the same, with due, rapidity.

2. *Putrefaction.*—The next great hypothesis was that of *putrefaction*, which, we are informed by Celsus,[1] was embraced by Plistonicus, a disciple of Praxagoras of Cos, who flourished upwards of three hundred years before the birth of Christ. Of late, it has had no advocates, but appears to have been the view embraced by Cheselden.[2] The reasons, urged in favour of it, have been;—the putrescible character of the materials employed as food; the favourable circumstances of a heat of 98° or 100°, and of moisture; and, by some, the fœtor of the excrements. The objections are, 1. That when the contents of the stomach are rejected, during chymification, they exhibit no evidence of putridity. 2. That in all the experiments, which have been made on the comparative digestibility of different substances, when it has been necessary to kill the animals at different stages of the digestive process, there has not been the slightest sign of putrefaction. 3. That opportunities frequently occur, for witnessing ravenous fishes and reptiles with an animal or portion of an animal,—too large to be entirely swallowed,—partly in the stomach, and the remainder in the gullet and mouth. In these cases, where the food has remained in this situation some days, the part contained in the throat has been found putrid, whilst that in the stomach has been entirely sweet; and lastly, in Spallanzani's and other experiments, to be detailed presently, it was found, when food, in a state of putridity, was taken into the stomach, or mixed with the gastric juice out of the stomach, that it recovered its sweetness. It has been already observed, that it is the custom, in some countries, to eat the *gibier* or *game* in a state of incipient putrefaction; yet the breath is not tainted by it.

3. *Trituration.*—The mathematical physiologists,—Borelli,[3] Hecquet,[4] Megallotti,[5] Pitcairne,[6] and others—after the example of Erisistratus,[7] attempted to refer the whole process of digestion to *trituration*, imagining, that the food is subjected in the stomach to an action similar to that of the pestle and mortar of the apothecary, or of the millstone; and that the chyle is formed like an emulsion. The most plausible arguments, in favour of this view of the subject, are drawn from the presumed analogy of the granivorous bird, whose stomach is capable of exerting an astonishing degree of pressure on substances submitted to it. There is no analogy, however, between the human stomach, and the gizzard of birds. The latter is a masticatory organ, and therefore possessed of the surprising powers which we have elsewhere described; whilst mastication, in man, is accomplished by distinct organs. No comparison can be instituted between the gentle oscillatory motion of the stomach, and the forcible compression exerted by the digastric muscle of the gizzard. The simple introduction of the finger through

[1] De Medicinâ, curâ E. Milligan, edit. 2da, p. 5, Edinb., 1831.
[2] Anatomy of the Human Body, &c., 8th edit., p. 155, Lond., 1763.
[3] De Motu Animalium; Addit. J. Bernouillii, M.D., Medit. Mathem. Muscul., Lugd. Bat., 1710.
[4] Traité de la Digestion, Paris, 1710.
[5] Haller, Elem. Physiol., xix. 5.
[6] Works, &c., Lond., 1715.
[7] Cels., loc. citat.

a wound of the abdomen has shown, that the compression exerted by it on its contents is totally insufficient to bruise any resisting substance. Moreover, we constantly see fruits,—as raisins and currants,—passing through the whole intestinal canal unchanged; whilst worms remain in the stomach—reside there—unhurt; and, we shall see presently, that the experiments of Réaumur and Spallanzani proved most convincingly, that digestion is effected independently of all pressure. The futility, indeed, of this mode of viewing the subject is signally illustrated by the fact, that, whilst Pitcairne estimated the power of the muscular fibres of the stomach at 12,951 pounds, Hales[1] thought that twenty pounds would come nearer the truth; and Astruc[2] valued its compressive force at five ounces!

4. *Fermentation.*—The system of fermentation had many partisans; amongst whom may be mentioned Van Helmont,[3] Sylvius,[4] Willis,[5] Boyle,[6] Grew,[7] Charleton,[8] Lower,[9] Raspail,[10] &c. Digestion, in this view, was ascribed to the chemical reaction of the elements of the food during their stay in the stomach;—the action being excited by food that had already undergone digestion, or by a leaven secreted for the purpose by the stomach itself. In favour of this view, it was attempted to show, that air is constantly generated in the organ, and that an acid is always produced as the result of fermentation,—the formation of chyme being referred by the greater number of physiologists to the food undergoing the vinous and acetous fermentations. The objections to this doctrine of fermentation are;—that digestion ought to be totally independent of the stomach, except as regards temperature; and the food ought to be converted into chyme, exactly in the same manner,—if it were reduced to the same consistence, and placed in the same temperature,—out of the body; which is not found to be the case. Bones are speedily reduced to chyme in the stomach of the dog, although they would remain unchanged for weeks, in the same temperature, out of the body. The facts of the voracious fishes before mentioned likewise prove the insufficiency of the hypothesis; according to which, digestion ought to be accomplished as effectually in the œsophagus as in the stomach. Yet it is found that, whilst the portion in the stomach is digested, the other may be unaltered, or be putrid. The truth is;—in healthy digestion, fermentation, in the ordinary acceptation of the term, does not occur; and, whenever the elements of the food react upon each other, it is an evidence of imperfect digestion; hence, fermentation is one of the most common signs of dyspepsia.

5. *Chemical solution.*—The theory of chemical solution, proposed by Spallanzani,[11] and subjected to modifications, has met with more favour

[1] Statical Essays, ii. 174, 4th edit., Lond., 1769.

[2] Traité de la Cause de la Digestion, &c., Toulouse, 1714; and Haller, loc. citat.

[3] Ortus Medicinæ, &c., Amstel., 1648.

[4] Opera, Genev., 1781.

[5] Diatribæ duæ Medico-Philosophicæ, &c., Lond., 1659.

[6] Works, vol. ii., Lond., 1772.

[7] Comp. Anat. of the Stomach, &c., Lond., 1681.

[8] Œcon. Anim. Exerc. 2.

[9] Tractatus de Corde, &c., Amstel., 1671.

[10] Chimie Organique, p. 356, Paris, 1833.

[11] Dissertations relative to the Natural History of Animals and Vegetables: sect. i., Lond., 1789.

from physiologists than any of the others that have been mentioned, and may be regarded as established. According to that observer, chymification is owing to the solvent action of a fluid, secreted by the stomach, which accumulates in that viscus between meals and during hunger,[1] and acts as a true menstruum on the substances exposed to it. This fluid,—to which he gave the name *gastric juice*,—he affirmed to be peculiar in each animal, according to its kind of alimentation,—corresponding, as regards its energy, with the rest of the digestive apparatus, and differing in its source in the series of animals; in some, proceeding from the follicles of the œsophagus; in others from those of the stomach; but always identical in the same animal; generally transparent, yellowish; of a saline taste; bitter; slightly volatile; and stronger in animals with a membranous than in those with a muscular stomach, and than in ruminant animals. To obtain the juice, Spallanzani opened animals, after they had been made to fast for a time; and collected the juice that had accumulated in their stomachs; or he made them swallow tubes pierced with holes, and filled with small sponges. By withdrawing these tubes, by means of a thread attached to them and suffered to hang out of the mouth, and expressing the sponges, he obtained the fluid in quantity sufficient for examination. To determine whether this fluid, obtained from fasting animals, was destined to chymify the food, he tried the following experiments. He caused numerous animals to swallow tubes filled with food, but pierced with holes, so that the juices of the stomach might be able to get into their interior; and found that chymification was effected, when he had taken the precaution to chew the substances before they were put into the tubes, or to triturate them; and the process was always more readily accomplished, the more easy the access of the fluids. On repeating these experiments on animals of various kinds, with a muscular or membranous, and musculo-membranous stomach; on pullets, turkeys, ducks, pigeons, rooks, frogs, salamanders, eels, serpents, sheep, cats, &c., he obtained the same results; and hence he affirmed, that trituration cannot be the essence of chymification. Réaumur,[2]—originally a believer in the doctrine of trituration,—had previously arrived at the same conclusion, by experiments of a similar kind. Spallanzani next repeated those experiments upon himself. Having well chewed different articles of food, he enclosed them in wooden tubes pierced with holes, and swallowed them; but, as the tubes caused pain in the bowels, he substituted small bags of linen. The substances contained in bags were digested without the bags being torn; a fact, which proved, that digestion must have been accomplished by means of a fluid, that penetrated them. In 1777, Dr. Stevens[3] repeated these experiments. He made a person swallow balls of metal, filled with masticated food, and pierced with holes: when the balls were voided,—thirty-six or forty-eight hours afterwards,—they were entirely empty. Lastly.—Spallanzani was desirous of seeing whether this solvent juice could effect digestion out of the body. He put some well-masticated food in small glass tubes, and mixed gastric juice with it. These

[1] It has been already stated, that the experiments of Dr. Beaumont have satisfactorily proved that no such accumulation takes place during hunger.

[2] Mémoir. de l'Acad. pour 1752.

[3] De Alimentorum Concoctione, § 24.

tubes he placed in his axilla, in order that they might be exposed to the same degree of heat as in the stomach; and in the space of fifteen hours, or of two days,—more or less,—the substances appeared to be converted into chyme. In these experiments he found it important to employ gastric juice, that had not been previously used, and to have a sufficient quantity of it.

From all these experiments, Spallanzani conceived it to be demonstrated, that chymification is a true chemical solution; and he endeavoured to deduce from them the degree of digestibility of different alimentary substances. Similar experiments were instituted by Dr. Beaumont.[1] In all cases, solution occurred as perfectly in the *artificial* as in the *real* digestions, but they were longer in being accomplished, for reasons which appear sufficient to explain the difference. In the former, the gastric secretion is not continuous; the temperature cannot be as accurately maintained, and there is an absence of those gentle motions of the stomach, which are manifestly so useful in accomplishing real digestion.

With regard to the precise nature of the gastric juice of Spallanzani, we have already observed that great contrariety of sentiment has prevailed; and that, in ordinary cases, it is impracticable to procure it unmixed with the other secretions of the digestive mucous membrane. Spallanzani affirmed, that the only properties he detected in it, were,—a slightly salt, bitterish taste; it was neither acid nor alkaline. Gosse[2] found it vary according to the nature of the animal,—whether herbivorous or carnivorous;—and to be always acid in the former. Dumas[3] held the same sentiments, and maintained from experiments on dogs, that it was acid or alkaline, according as the animal had fed on vegetable or animal diet. He declared it, moreover, to be mawkish, thick, and viscid. Viridet[4] and others affirmed that it was always acid. Mr. Hunter[5] was not inclined to suppose, that there is any acid in the gastric juice as a component or essential part of it, "although an acid is very commonly discovered even when no vegetable matter has been introduced into the stomach." Scopoli[6] analyzed the gastric juice of the rook, and found it to consist of water, gelatin, a saponaceous matter, muriate of ammonia, and phosphate of lime. Carminati[7] describes it as salt, bitter, and frequently acid; and MM. Macquart[8] and Vauquelin,[9] in the gastric juice of the ruminant animal, found albumen and free phosphoric acid.[10] All these analyses were made on the mixed fluid, to which the term *gastric juice* has been applied. That such a mixed fluid does exist in the stomach at the time of chymification, and is largely concerned in the process, is proved by the facts already mentioned, as well as by the following. M. Magendie[11] asserts, that one of his pupils—M. Pinel—

[1] Op. citat., p. 139.
[2] Expériences sur la Digestion, § 81, Génev., 1783.
[3] Principes de Physiologie, Paris, 1806.
[4] Tractatus Novus de Primâ Coctione, &c., Genev., 1691.
[5] Observations on Certain Parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 134., Philad., 1840.
[6] In Spallanzani, § 244.
[7] Ricerche sulla Natura, &c., del Succo Gastrico, Milano, 1785; or Journal Phys., t. xxiv.
[8] Mém. de la Société de Méd., Paris, 1786.
[9] Fourcroy, Elém. de Chim., tom. iv.
[10] See Burdach, Die Physiologie als Erfahrungswissenschaft, v. 240 und 431, Leips., 1835.
[11] Précis, &c., ii. 11.

could procure, in a short time after swallowing a little water or solid food, as much as half a pint. M. Pinel "possessed the faculty of vomiting at pleasure." In this way, he obtained from his stomach, in the morning, about three ounces of fluid, which was analyzed by M. Thénard, who found it composed of a considerable quantity of water, a little mucus, and salts with a base of soda and lime; but it was not sensibly acid, either to the tongue or to reagents. On another occasion, M. Pinel obtained two ounces of fluid in the same manner. This was analyzed by M. Chevreul, and found to contain much water, a considerable quantity of mucus, lactic acid—united to an animal matter, soluble in water, and insoluble in alcohol,—a little muriate of ammonia, chloride of potassium, and some chloride of sodium.

Messrs. Tiedemann and Gmelin[1] procured the gastric fluid by making animals, that had fasted, swallow indigestible substances, as flints. It always appeared to them to be produced in greater quantity, and to have a more acid character, in proportion as the alimentary matter was less digestible and less soluble; and they assign it, as constituents,—chlorohydric acid; acetic acid; mucus; no, or very little, albumen; salivary matter; osmazome; chloride of sodium, and sulphate of soda. In the ashes, remaining after incineration, were, carbonate, phosphate, and sulphate of lime, and chloride of calcium. MM. Leuret and Lassaigne[2] assign its composition, in one hundred parts, to be,—water, ninety-eight; lactic acid; muriate of ammonia; chloride of sodium; animal matter soluble in water; mucus; and phosphate of lime, two parts. M. Braconnot[3] examined the gastric juice of a dog, and found it to contain—free chlorohydric acid in great abundance; muriate of ammonia; chloride of sodium in very great quantity; chloride of calcium; a trace of chloride of potassium; chloride of iron; chloride of magnesium; colourless oil of an acid taste; animal matter soluble in water and alcohol, in very considerable quantity; animal matter soluble in weak acids; animal matter soluble in water, and insoluble in alcohol (*salivary matter* of Gmelin); mucus; and phosphate of lime. In the winter of 1832–3, the author was favoured by Dr. Beaumont,[4] with a quantity of the gastric secretion obtained from the individual with the fistulous opening into the stomach, which was examined by himself, and his friend, the late Professor Emmet, of the University of Virginia, and found to contain free chlorohydric and acetic acids, phosphates, and chlorides, with bases of potassa, soda, magnesia, and lime, and an animal matter—probably pepsin—soluble in cold water, but insoluble in hot. The quantity of free chlorohydric acid was surprising: on distilling the fluid, the acids passed over, the salts and animal matter remaining in the retort: the amount of chloride of silver thrown down on the addition of the nitrate of silver to the distilled fluid, was astonishing. The author had many opportunities for examining the gastric secretion obtained from the case in question. At all times, when pure or un-

[1] Op. cit. [2] Recherches, &c., Paris, 1825.

[3] Journal de Chimie Médicale, tom. ii., ser. 2, 1836, and Records of General Science, Jan., 1836.

[4] See a letter from the author to Dr. Beaumont, in Beaumont's Experiments, &c., on the Gastric Juice, p. 77; and the author's Elements of Hygiène, p. 216, Philad., 1835.

mixed except with a portion of the mucus of the lining membrane of the digestive tube, it was a transparent fluid, having a marked smell of chlorohydric acid; and of a slightly salt, and very perceptibly acid, taste. It matters not, therefore, that M. Blondlot,[1] in his experiments on the gastric secretions of dogs and other animals, obtained by artificial fistulous openings made into the stomach, did not find, when distilled, that they exhibited any acid reaction, whilst the residue in the retort was always strongly acid. The results referred to by the author as regards the gastric juice of man were positive and uniform; and established, that it always contains a large quantity of chlorohydric acid. After this it seems unnecessary to examine into the statement of M. Blondlot, that the true and almost only source of the acidity of healthy gastric fluid is the presence of acid phosphate salts. If, at least, we admit this to be the case in animals, it is assuredly not so in man. The remark applies equally to the experiments of Dr. R. D. Thompson on the gastric secretions of the sheep and pig.[2] By these observers, the results obtained from the examination of the gastric secretions in man, seem to have been passed over, and they have deduced their inferences from those of animals, which may, in part, account for the great discrepancy in their statements.[3]

The source of the chlorine or chlorohydric acid, as Dr. Prout[4] suggests, must be the common salt existing in the blood, which, he conceives, is decomposed by galvanic action. The soda, set free, remaining in the blood, a portion being "requisite to preserve the weak alkaline condition essential to the fluidity of the blood;" but the larger part being directed to the liver to unite with the bile. This is plausible; but, it need scarcely be added, not the less hypothetical. Drs. Purkinje and Pappenheim[5] are of a similar opinion in regard to the source of the chlorohydric acid. From their galvanic experiments they think it follows, that the juices mixed with the food in the natural way, saliva, mucus, the portions of chloride of sodium present therein, and still more the gastric mucous membrane itself, develope as much as is required; and that if the nervous action in the stomach be either identical with, or analogous to, galvanism, it would be sufficient to account for the secretion of the quantity of chlorohydric acid requisite for digestion, without the assumption of a special organ of secretion.

M. Blondlot[6] denies—and Liebig[7] formerly did likewise—that in health lactic acid exists in the stomach. In certain diseases, according to the latter, both it and mucilage are formed from the starch, and sugar of the food; and he affirms, that the property possessed by these substances of passing, by contact with animal substances, in a

[1] Traité Analytique de la Digestion, Paris, 1844. An abstract of his views is given by Mr. Paget, Brit. and For. Med. Rev., Jan., 1845, p. 270.
[2] Ranking's Abstract, vol. i., Pt. 2, Amer. edit., p. 271, New York, 1846.
[3] Carpenter, Principles of Physiology, 4th Amer. edit., p. 494, Philad., 1850; and Kirkes and Paget, Manual of Physiology, Amer. edit., p. 170, Philadelphia, 1849.
[4] Bridgewater Treatise, Amer. edit., p. 268, Philad., 1834.
[5] Müller's Archiv. für Anatomie, u. s. w. Heft 1, 1838, noticed in Brit. and For. Med. Rev., Oct., 1838, p. 529.
[6] Op. cit.
[7] Animal Chemistry, Gregory's and Webster's edit., p. 107, Cambridge, 1842.

state of decomposition, into lactic acid, has induced physiologists without farther inquiry, to assume that lactic acid is produced during digestion. He now, however, admits its existence in health,[1] and with Dr. R. D. Thompson and MM. Bernard and Barreswil considers it to be an important agent in the digestive process. With some other chemists, he denies the existence of free chlorohydric acid in the stomach, and believes, that when it is obtained by the simple distillation of the gastric juice it is formed by the reaction of the lactic and phosphoric acids, which are present in the fluid, on the chlorides; and recently, Lehmann found, when he experimented on the stomachs of dogs placed in vacuo in such a manner as to cause the vapours from the gastric juice to pass through a tube containing a solution of nitrate of silver, that there was no indication of free chlorohydric acid until the fluid had become so concentrated as to permit the action of the lactic acid on the earthy chlorides. His results would tend to confirm the later conclusions of Liebig, as well as those of MM. Bernard and Barreswil, as to the nature of the acid on the gastric juice of certain animals at least.[2] It is proper to remark, however, that neither Prout nor Braconnot could detect the lactic acid in the gastric juice; and, moreover, it does not appear to be formed in artificial digestion.[3]

The diversity of results obtained by chemical analysis; the difficulty of comprehending how the same fluid can digest substances of such opposite character; and the uncertainty we are in, regarding the organs concerned in its production, have led some physiologists to doubt the existence of any such *gastric juice* or solvent as that described by Spallanzani. M. Montègre,[4] for example, in the year 1812, presented to the French Institute a series of experiments, from which he concluded, that the gastric juice of Spallanzani is nothing more than saliva, either in a pure state, or changed by the chymifying action of the stomach and become acid. As M. Montègre was able to vomit at pleasure, he obtained the gastric juice, as it had been done by previous experimenters, in this manner, whilst fasting. He found it frothy, slightly viscid, and turbid; depositing, when at rest, some mucous flakes; and commonly acid; so much so, indeed, as to irritate the throat, and render the teeth rough. He was desirous of proving, whether this fluid was in any manner inservient to chymification. For this purpose, he began by ejecting as much as possible by vomiting; and, afterwards, swallowed magnesia to neutralize what remained. On eating afterwards, the food did not appear less chymified, nor was it less acid; whence he concluded, that, instead of the fluid being the agent of chymification, it was nothing more than saliva and the mucous secretions of the stomach, changed by the chymifying action of that viscus. To confirm himself in this view, he repeated, with it, Spallanzani's experiments on artificial digestion; making, at the same sime, similar experiments with saliva:

[1] Chemistry of Food, London, 1847.

[2] Archiv. der Pharmacie, c. p. 79, cited in the British and Foreign Medico-Chirurgical Review, p. 261, Jan., 1849.

[3] A full account of the various views in regard to the gastric acid is given by Frerichs, Art. Verdauung, Wagner's Handwörterbuch der Physiologie, 21ste Lieferung, s. 780, Braunschweig, 1849; and Bérard, Cours de Physiologie, 11e Livraison, p. 97, Paris, 1849.

[4] Expér. sur la Digestion, p. 20, Paris, 1824.

the results were the same in both cases. When gastric juice, not acid, was put into a tube, and placed in the axilla,—as in Spallanzani's experiments,—in twelve hours it was in a complete state of putrefaction. The same occurred to saliva placed in the axilla. Gastric juice, in an acid state, placed there, did not become putrid, but this seemed to be owing to its acidity; for the same thing happened to saliva, when rendered acid by the addition of a little vinegar; and even to the gastric juice,—used in the experiment just referred to,—when mixed with a little vinegar. Again:—he attempted artificial digestions with the gastric juice, acid and not acid; fresh and old; but they were unsuccessful. The food always became putrid; but sooner when the juice employed was not acid; and, if it sometimes liquefied before becoming putrid, this was attributed to the acidity of the juice, as the same effect took place, when saliva, mixed with a little vinegar, was employed. M. Montègre, moreover, observed, that the food rejected from the stomach was longer in becoming putrid, in proportion to the time it had been subjected to the chymifying action of the stomach; and he concluded, that the fluid, which is sometimes contained in the empty stomach, instead of being a menstruum kept in reserve for chymification, is nothing more than the saliva continually sent down into that viscus, and that its purity or acidity depends upon the chymifying action of the stomach.[1]

As regards the fluid met with in the stomach of fasting animals, M. Montègre's remarks may be true in the main; but we have too many evidences in favour of the chemical action of some secretion from the stomach during digestion to permit us to doubt the fact for a moment. Besides, some of Montègre's experiments have been repeated with opposite results. MM. Leuret and Lassaigne,[2] and Dr. Beaumont[3] performed those relating to digestion after the manner of Spallanzani, and succeeded perfectly; whilst they failed altogether in producing chymification with saliva, either in its pure state, or when acidulated with vinegar. By steeping the mucous membrane of an animal's stomach in an acid liquor, a solution is obtained, to which Eberle[4] gave the name *pepsin*. This solution has the property of dissolving organic matter in a much higher degree than diluted acids. It dissolves coagulated albumen, muscular fibre, and animal matters in general. In an experiment, one grain of the digestive matter dissolved one hundred grains of coagulated white of egg. Eberle thought that all mucus has the property, when acidulated, of inducing decomposition and subsequent solution of the food; but it would appear, that no other mucus than that of the gastric mucous membrane, when acidulated, possesses it,[5] and, consequently, that there must be a peculiar substance, *pepsin*, which may be regarded as the true digestive principle.[6] This principle was not obtained by Schwann in a pure state; but M. Wasmann[7] would appear to have suc-

[1] Chaussier and Adelon, in Dict. des Sciences Médicales, xx. 422.
[2] Recherches sur la Digestion, Paris, 1825. [3] Op. citat., p. 139.
[4] Physiologie der Verdauung nach Versuchen, u. s. w., Wurzburg, 1834; Müller, Archiv. Heft 1, 1836, or London Lancet, p. 19, March 31, 1838.
[5] Müller, Elements of Physiology, by Baly, pp. 518 and 542, London, 1838.
[6] Müller and Schwann, in Müller's Archiv. Heft 1, 1836; and Müller, op. citat.
[7] Journ. de Pharmacie; and American Journal of Pharmacy, for Oct. 1840, p. 192.

ceeded better. A solution, containing only $\frac{1}{60000}$ part of pepsin and slightly acidulated, is said to dissolve the white of an egg in six or eight hours.

Even were the evidence adduced less positive, the following phenomena would be overwhelming in favour of the existence of some gastric secretion concerned in the digestive changes in that organ. Besides the fact of the most various and firm substances being reduced to chyme in the stomach, we find the secretions from its lining membrane possessing the power of coagulating albuminous fluids. It is upon the coagulating property of these secretions, that the method of making cheese is dependent. Rennet, employed for this purpose, is an infusion of the digestive stomach of the calf, which, on being added to milk, converts the albuminous portion into curd; and it is surprising how small a quantity is necessary to produce this effect. Messrs. Fordyce[2] and Young,[3] of Edinburgh, found that six or seven grains of the inner coat of a calf's stomach, infused in water, afforded a liquid, which coagulated more than one hundred ounces of milk,—that is, more than six thousand eight hundred and fifty-seven times its own weight; and yet its weight was probably but little diminished. The substance that possesses this property does not appear to be very soluble in water; for the inside of a calf's stomach, after having been steeped in water for six hours, and well washed, still furnishes a liquor or infusion, which coagulates milk. Liebig[4] has denied, that the fresh lining membrane of the stomach of the calf, digested in weak chlorohydric acid, gives to that fluid the power of dissolving boiled flesh or coagulated white of egg;—but Dr. Pereira[5] affirms, that he has found, by experiment, that a digestive liquor can be prepared from the fresh undried stomach of a calf. This has, indeed, been shown on the best authority long ago. Mr. Hunter, for example, made numerous experiments upon the coagulating power of the secretions of the stomach, which show, that it is found in the stomachs of animals of very different classes. The lining of the fourth stomach of the calf is in common use, in a dried state, for the purpose mentioned above; and it has been proved, that every part of the membrane possesses the same property. Mr. Hunter found, by experiment, that the mucus of the fourth cavity of a slink calf, made into a solution with a small quantity of water, had the power of coagulating milk; but that found in the three first cavities possessed no such power. The former, even after it had been kept several days, and was beginning to be putrid, retained the property. The duodenum and jejunum, with their contents, likewise coagulated milk; but the process was so slow as to give rise to the suggestion, that it might have occurred independently of the intestines employed for the purpose. He found, that the inner membrane of the fourth cavity in the calf, when old enough to be killed for veal, had the same property. Portions of the

[1] Graham's Elements of Chemistry, Amer. edit., p. 695, Philad., 1843, and Thomson's Animal Chemistry, p. 229, Edinb., 1843.
[2] A Treatise on the Digestion of Food, p. 57, 2d edit., Lond., 1791.
[3] Thomson's System of Chemistry, 6th edit., iv. 596.
[4] Animal Chemistry, Webster's Amer. edit., Cambridge, 1842.
[5] Treatise on Food and Diet, Amer. edit., p. 36, New York, 1843.

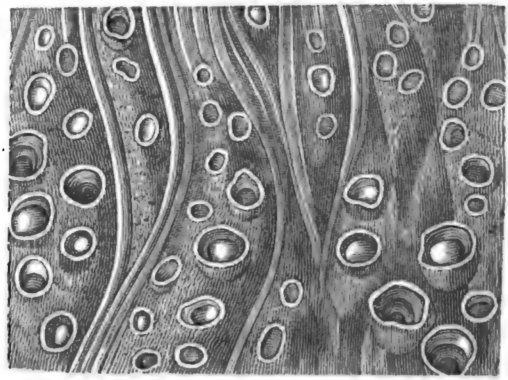
cuticular, of the massy glandular part, and of the portion near the pylorus of the boar's stomach, being prepared as rennet, it was found, that no part had the effect of producing coagulation but that near the pylorus, where the gastric glands of the animal are especially conspicuous. The crop and gizzard of a cock were salted, dried, and afterwards steeped in water. The solution, thus obtained, was added to milk: the portion of the crop coagulated it in two hours; that of the gizzard in half an hour. The contents of a shark's stomach and duodenum coagulated it instantaneously. Pieces of the stomach were washed clean, and steeped in water for sixteen hours. The solution coagulated milk immediately. Pieces of the duodenum produced the same effect. When the milk was heated to 96°, the coagulation took place in half an hour; when cold, in an hour and a quarter. The stomachs of the salmon and thornback, made into rennet, coagulated milk in four or five hours.

But those experiments of Mr. Hunter do not inform us of the particular secretions that are productive of the effect. They would, indeed, rather seem to show, that it is a general property of the whole internal membrane. To discover the exact seat of the secretion, and especially whether it be not in the gastric glands, Sir Everard Home[1] selected those of the turkey; which, from their size, are better adapted for such an experiment than those of any other bird, except the ostrich. A young turkey was kept a day without food, and then killed. The gastric glands were carefully dissected separately from the lining of the cardiac cavity; cutting off the duct of each before it pierced the membrane, so that no part but the glands themselves were removed. Forty grains, by weight, of these glands were added to two ounces of new milk; and similar experiments were made with rennet; with the lining of the cardiac cavity of the turkey; and with the inner membrane of the fourth cavity of the calf's stomach. Coagulation and separation into curds and whey were first effected by the rennet. Next to this, and simultaneously, came the gastric glands, and the fresh stomach of the calf; and lastly, the cardiac membrane of the turkey. From these experiments, Sir Everard concluded, that the power of coagulation is in the secretion of the gastric glands; and that the power is communicated to other parts, by their becoming more or less impregnated with it.

The marginal figure, copied from an engraving of the microscopic observations of Mr. Bauer, exhibits the gastric glands of the human œsophagus magnified fifteen times. These glands are the lining of the lower part of the œsophagus; and have the appearance of infundibular cells, whose depth does not exceed the thickness of the membrane. This structure, although different from that of the gastric glands of birds, is a nearer approach to it than is to be met with in any part of the inner surface of the stomach or duodenum. It also resembles them, in the secretion which it produces coagulating milk, whilst none of the inspissated juices, met with in these cavities, according to Sir Everard, affect milk in the same way. From these facts, he thinks, there can be no longer any doubt entertained, that the gastric glands have the same situation respecting the cavity of the stomach as in birds. Yet

[1] Lectures on Comparative Anatomy, i. 299, Lond., 1814, and iii. 134, Lond., 1823.

Fig. 248.



Gastric Glands of the Œsophagus magnified fifteen times.

M. Montègre[1] denies that the gastric juice has any coagulating power!

In some experiments, undertaken by M. J. F. Simon[2] with a view to determine, whether the stomach of the child possesses the same properties of coagulating milk as that of the calf, he found that cow's milk was not coagulated by it, but that, when a quantity of the colostrum of the mother of a child, which died when five days old, was obtained, and a piece of calf's stomach was introduced into it, the milk coagulated.

Another property, manifestly possessed by the secretion in question, is that of preventing putrefaction, or of obviating it in substances exposed to its action. Montègre and Thackrah[3] deny it this property, but there can be no doubt of its existence. Spallanzani, Fordyce, and others, have ascertained, that in those animals which frequently take their food in a half putrid state, the first operation of the stomach is to disinfect, or remove the fœtor from the aliment received into it. We have already alluded to many facts elucidative of this power. Helm of Vienna,[4] in the case of a female who had a fistulous opening in her stomach, observed, that substances which were swallowed in a state of acidity or putridity, soon lost those qualities in the stomach; and the same power of resisting and obviating putrefaction has been exhibited in experiments made out of the body. Nothing could be more unequivocal, as regards the possession of this property by the gastric fluid, than the experiments of Dr. Beaumont and the author,[5] with the secretion obtained from the subject of his varied investigations. In the presence of the author's friend, N. P. Trist, Esq.—then consul of the United States at Havana,—the odour of putrid food was as speedily removed by it as by chlorinated soda, employed at the same time on other portions. The explanation of this property, as well as that of coagulation, has been a stumbling-block to the chemical physiologist. "We can only say concerning it," says Dr. Bostock,[6] "that it is a chemical operation, the nature of which, and the successive steps by which it is produced, we find it difficult to explain; at the same time, that we have very little, in the way of analogy, which can assist us in referring it to any more general principle, or to any of the established laws of chemical affinity."

[1] Expériences sur la Digestion, Paris, 1824.
[2] Müller's Archiv. Heft 1, 1839, cited in Brit. and For. Med. Rev., Oct, 1839, p. 549.
[3] Lectures on Digestion and Diet, p. 14, Lond., 1824.
[4] Rudolphi, Grundriss der Physiologie, 2er Band, 2te Abtheil., s. 114, Berlin, 1828.
[5] See the author's Elements of Hygiène, p. 216, Philad., 1835.
[6] Edit. citat., p. 571.

The cases of what are termed *digestion of the stomach after death* afford us, likewise, remarkable examples of the presence of some powerful agent in the stomach; as well as of the resistance to chemical action, offered by living organs. Powerful as the action of the gastric juice may be, in dissolving alimentary substances, it does not exert it upon the coats of the stomach during life. Being endowed with vitality, they effectually resist it. But when that viscus has lost its vitality, its parietes yield to the chemical power of the contained juices, and become softened, and, in part, destroyed. M. Hunter[1] found the lining membrane of the stomach destroyed, in several parts, in the body of a criminal, who, for some time before his execution, had been prevailed upon, in consideration of a sum of money, to abstain from food. Since Hunter's time, numerous examples have occurred, and been recorded by Messrs. Baillie, Allan Burns, Haviland, Grimaud, Pascalis, Cheeseman, J. B. Beck, Chaussier, Yelloly, Gardner, Treviranus, Gödecke, Jäger, Carswell, and others.[2] The fact is of importance in medical jurisprudence; and, until a better acquaintance with the subject, would, doubtless, have been set down as strong corroborative evidence in cases of suspected poisoning. It is now established that solution of the stomach may take place after death, without there being reason for supposing that any thing noxious had been swallowed.

The experiments of Drs. Wilson Philip[3] and Carswell[4] are corroborative of this physiological action on the gastric juice. On opening the abdomen of rabbits, that had been killed immediately after having eaten, and allowed to lie undisturbed for some time before examination, the former found the great end of the stomach soft, eaten through, and sometimes altogether consumed; the chyme being covered only by the peritoneal coat, or lying quite bare for the space of an inch and a half in diameter: and, in this last case, a part of the contiguous intestines was also destroyed; whilst the cabbage, which the animal had just taken, lay in the centre of the stomach unchanged, if we except the alteration that had taken place, in the external parts of the mass it had formed, in consequence of imbibing gastric fluid from the half-digested food in contact with it. Why the perforation takes place, without the food being digested, is thus explained by Dr. Philip. Soon after death, the motions of the stomach, which are constantly carrying on the most digested food towards the pylorus, cease. The food that lies next to the surface of the stomach, thus becomes fully saturated with gastric fluid; neutralizes no more; and no new food being presented to the fluid it acts on the stomach itself, now deprived of life, and equally subjected to its action with other dead animal matter. It is extremely remarkable, however, that the gastric fluid of the rab-

[1] Phil. Transact., lxii.; and Observations on certain parts of the Animal Economy, with notes by Prof. Owen, Amer. edit., p. 144, Philad., 1840.

[2] Beck's Medical Jurisprudence, 6th edit., ii. 311, Albany, 1838; Carswell's Path. Anat., No. 5, Lond., 1833; and T. Wilkinson King, Guy's Hospital Reports, vii. 139, Lond., 1842; and a case communicated to the author by Dr. Thomas M. Flint, in which the stomach had separated from the œsophagus, recorded in Med. Examiner, p. 715, for December, 1848.

[3] Treatise on Indigestion, Lond., 1821.

[4] Ibid. and Edinb. Med. and Surg. Journal, Oct., 1830; and art. Perforation of the Hollow Viscera, in Cyclopædia of Practical Medicine, P. xvi. p. 272, Lond., 1833.

bit, which, in its natural state, refuses animal food, should so completely digest the stomach, as not to leave a trace of the parts acted upon. Dr. Philip remarks, that he has never seen the stomach eaten through except at the larger end; but, in other parts, the external membrane has been injured. Mr. A. Burns,[1] however, affirms, that in several instances he found the forepart of the stomach perforated, about an inch from the pylorus, and midway between the smaller and larger curvatures.

From all these facts, then, we are justified in concluding, that the food in the stomach is subjected to the action of a secretion, which alters its properties, and is the principal agent in converting it into chyme.

But many physiologists, whilst they admit, that the change effected in the stomach is of a chemical character, contend, that the nature of the action is unlike what takes place in any other chemical process, and is, therefore, necessarily *organic* and *vital*, and appertaining to *vital chemistry*. Such are the sentiments of Messrs. Fordyce,[2] Broussais,[3] Chaussier, and Adelon,[4] and others. Dr. Prout suggests, that the stomach must have, within certain limits, the power of *organizing* and *vitalizing* the different alimentary substances; so as to render them fit for being brought into more intimate union with a living body, than the crude aliments can be supposed to be. It is impossible, he conceives, to imagine, that this organizing agency of the stomach can be chemical. It is vital, and its nature completely unknown. The physiologist should not, however, have recourse to this explanation, until every other has failed him. It is, in truth, another method of expressing his ignorance, when he affirms, that any function is executed in an *organic* or *vital* manner; nor is this mode of explaining the conversion of the aliment into chyme necessary; the secretion of the matters that are the great agents of chymification is doubtless vital; but when once secreted, the changes, effected upon the food, are probably unmodified by any vital interference, except what occurs from temperature, agitation, &c., which can only be regarded as auxiliaries in the function. It is in this way, that digestion is influenced by the nervous system.

The effect of the different emotions on the digestive function is often evinced, and has already been alluded to; but the importance of the nervous influence to it has been elucidated, in an interesting manner to the physiologist, of late years chiefly. Baglivi,[5] having tied the nerves of the eighth pair in dogs, found that they were affected with nausea and vomiting, and obstinately refused food. Since Baglivi's time, the same results have been obtained by many physiologists. M. De Blainville, having repeated the operation on pigeons, found the vetch in their crops entirely unchanged, and chymification totally prevented. Messrs. Legallois,[6] Brodie,[7] Philip,[8] Dupuy, Clarke Abel, Hastings,[9] and others—

[1] Edinb. Med. and Surg. Journal, vi. 132. [2] On the Digestion of Food, 2d edit., Lond., 1791.
[3] Traité de Physiologie, &c., translated by Drs. Bell and La Roche, p. 323.
[4] Dict. des Sciences Médicales, ix.
[5] Opera Omnia, Lugd. Bat., 1745. [6] Sur le Principe de la Vie, p. 214, Paris, 1842.
[7] Phil. Trans. for 1814. [8] Experimental Inquiry, &c., Lond., 1817.
[9] Journal of Science and Arts., vii. ix. x. xi. and xii.

on carefully repeating the experiments—announced, that, after this operation, the digestive process was entirely suspended.[1] The result of these experiments was, however, contested by several physiologists of eminence, who affirmed, that, after the division of the eighth pair, digestion continued nearly in the natural state, or, at most, was only slightly impeded. Mr. Broughton[2] asserted, that he had made the section on eleven rabbits, one dog, and two horses; and that digestion was not destroyed. M. Magendie[3] expresses his belief, that the arrest of chymification, where it was observed, was owing to the disturbance of respiration caused by the division of the nerves; and he states that digestion continued when care was taken to cut the nerve within the thorax, lower down than the part which furnishes the pulmonary branch. MM. Leuret and Lassaigne assert,[4] that they found chymification continue, notwithstanding the division of these nerves; and Dr. G. C. Holland[5] thinks he has proved, that the suspension of the digestive function is not produced by the influence of the nerves being withdrawn from the stomach, but by the disturbance of the circulatory system; for when the natural conditions of this system were maintained, after the division of the nerves, the function of digestion still continued to be properly performed; showing that the nervous connexion between the brain and stomach is not essential to the process of digestion, the secretion of the gastric solvent, or the possession of contractility by the muscular fibres of the stomach.

In opposition to these experiments, those of M. Dupuytren may be adduced. He divided, separately, the portions of the eighth distributed to the pulmonary, circulatory, and digestive apparatuses, and always found, when the section was made below the pulmonary plexus, that chymification was suspended. But how are we to explain the discrepancy between these results, and those of Messrs. Broughton and Magendie? M. Adelon[6] has supposed, that as the eighth pair is not the only nerve distributed to the stomach,—the great sympathetic sending numerous filaments to it,—these filaments, in the experiments of Messrs. Broughton and Magendie, might have been sufficient to keep up for some time the chymifying action of the stomach; and, again, he suggests, whether the nervous influence may not have still persisted for a time after the section of the nerve, like other nervous influences, which, he conceives, continue for some time even after death; and lastly, he thinks it probable, that, in the cases in which chymification continued, the experiment was badly performed. Most of these reasons, however, would apply with as much force to the experiments on the other side of the question. Why were not the agency of the great sympathetic, and the continuance of the nervous influence for some time after the section of the nerve, evidenced in the experiments of Dupuytren, Wilson Philip, Hastings, and others?

[1] Ley, in App. to Laryngismus Stridulus, p. 447, Lond., 1836.
[2] Ibid., x. 292. [3] Précis, &c., ii. 102.
[4] Edinburgh Med. and Surg. Journal, xciii. 365; and Recherches sur la Digestion, Paris, 1825.
[5] Inquiry into the Principles, &c., of Medicine, i. 444, Lond., 1834.
[6] Physiologie de l'Homme, &c., 2de édit., vol. ii. Paris, 1829.

More recent experiments by Messrs. Wilson Philip,[1] Breschet, Milne Edwards, and Vavasseur,[2] have shown, that the mere division of the nerves, and even the retraction of the divided extremities for the space of one-fourth of an inch, does not prevent the influence from being transmitted along them to the stomach; but that if a portion of the nerve be actually removed, or the ends folded back, chymification is wholly or partly suspended.[3] Most of the experimenters agree with Sir Benjamin Brodie in the opinion, that chymification is suspended owing to the secretion of the gastric juice having been arrested by the division of the nerves under whose presidency it is accomplished. MM. Breschet and Milne Edwards, however, conceive, that the effect is owing to paralysis of the muscular fibres of the stomach produced by the section of the nerves; in consequence of which the different portions of the alimentary mass are not brought properly into contact with the coats of the stomach, so as to be exposed to the action of its secretions; and they affirm, that when the galvanic influence is made to pass along the part of the nerve attached to the stomach, its effect is to restore the due action of the fibres; and, that a mechanical irritant, applied to the lower end of the divided nerves, produces a similar kind of change on the food in the organ; from which they conclude, that the use of the par vagum, as connected with the functions of the stomach, is to bring the alimentary mass into necessary contact with the gastric secretions. These experiments were repeated in London by Mr. Cutler, under the inspection of Dr. Philip and Sir B. Brodie; but the effects of mechanical irritation of the lower part of the divided nerve did not correspond with those observed by MM. Breschet and Milne Edwards.[4]

The experiments of F. Arnold,[5] and of MM. Bouchardat and Sandras[6] lead them also to infer, that the nerves of the stomach appear to influence chymification in so far as the process depends upon the various motions of the organ.

M. Longet[7] has endeavoured to reconcile these discordant results. Having opened many dogs, he ascertained, that in the greater number, irritation of the pneumogastric nerves induced contraction of the stomach. Frequently, during his experiments, he saw the stomach assume the hour-glass form. In a few dogs, the movements of the stomach, on the irritation of the nerve, were scarcely perceptible. After repeating his experiments on forty dogs, he recognised that the difference in the results obtained depended on the condition of the stomach itself. Thus, if the animal was opened when it was full, irritation of the pneumogastric nerves caused manifest movement; but, when empty, scarcely any was excited: the movements, in fact, were feeble in pro-

[1] Philos. Transact. for 1822. [2] Archives Générales de Méd., Août, 1823.
[3] Ware, North American Medical and Surgical Journal., Philad., 1848.
[4] Bostock's Physiology, 3d edit., p. 523, London, 1836.
[5] Lehrbuch der Physiologie des Menschen, Zurich, 1836–7; noticed in British and Foreign Medical Review for Oct., 1839, p. 478.
[6] Annuaire de Thérapeutique, pour 1848, p. 283, Paris, 1848.
[7] Comptes Rendus, Févr., 1842. See, also, Bischoff, in Müller's Archiv., Berlin, 1843, and Prof. E. Weber, art. Muskelbewegung, in Wagner's Handwörterbuch der Physiologie, 15te Lieferung, s. 41, Braunschweig, 1846.

portion to the time that had elapsed from the period of chymification, or of filling the stomach. M. Longet thinks, that these facts account for the different results arrived at by experimentalists in regard to the influence of the pneumogastric nerves over the movements of the stomach; for, if the same experiments were made when the stomach was in different states, they might readily lead to opposite conclusions. He was never able to excite any movement of the coats of the stomach, by irritating or galvanizing the filaments of the great sympathetic or the semilunar ganglia.

On the whole, the proposition of Dr. Philip,—that if the eighth pair be divided in such a manner as to effectually intercept the passage of the nervous influence, digestion is suspended,—is generally considered to be established; although it must, we think, be admitted with Mr. Mayo,[1] that the rationale of the subject remains involved in great uncertainty. Like other secretions, that of the gastric juice, although capable of being modified by the nervous influence, cannot be regarded as immediately dependent upon it. The secretion, of the true acid character and solvent powers, is not always checked by the section of the nerves, and the experiments of Dr. John Reid[2] and others have sufficiently shown, that the integrity of those nerves is not a condition absolutely necessary for secretion in the stomach, whilst at the same time they prove, that the amount of secretions usually poured into the interior of that organ may be modified in an important manner by causes acting through those nerves.[3] It is denied, however, by Professor J. Müller, that galvanism has any influence in re-establishing the gastric secretion, when it has been checked by their division.

Finally:—Dr. Philip found, that every diminution of the nervous influence,—the section of the medulla spinalis at the inferior part, for example,—deprives the stomach of its digestive faculty; and MM. Edwards and Vavasseur obtained the same result by the removal of a certain portion of the hemispheres of the brain, or by the injection of opium into the veins in sufficient quantity to throw the animal into deep coma. Much must, of course, be dependent on the deranging influence of the experiments. By means of the fistulous openings into the stomachs of dogs, first instituted by M. Blondlot, (see page 586,) M. Bernard[4] undertook fresh experiments on this unsettled topic. A dog's digestion was watched for eight days, and found to be well accomplished. On the ninth day, after twenty-four hours' fast, M. Bernard sponged out the stomach, which contracted on the contact of the sponge, and at once secreted a large quantity of gastric fluid. He then divided the pneumogastric nerves in the middle of the neck, and immediately the mucous membrane, which had been turgid, became pale, as if exsanguious; the movements of the stomach ceased; the secretion of gastric fluid was instantaneously arrested, and a quantity of neutral ropy mucus was soon produced in its place. After this, digestion was

[1] Outlines of Human Physiology, 4th edit., p. 122, Lond., 1837.
[2] Edinb. Med. and Surg. Journal, April, 1839; and art. Par Vagum, in Cyclop. of Anat. and Physiol., pt. xxviii. p. 899, Lond., April, 1847.
[3] Longet, Traité de Physiologie, ii. 339, Paris, 1850.
[4] Gazette Médicale de Paris, 1 Juin, 1844.

not duly performed; milk was no longer coagulated; raw meat remained unchanged; and the food, consisting of meat, milk, bread, and sugar, which the dog had before thoroughly digested, remained for a long time neutral, and at length acquired acidity only from its transformation into lactic acid. In the stomachs of other dogs, after the division of the nerves, he traced the transformation of cane sugar into grape sugar in three or four hours; and in ten or twelve hours, the transformation into lactic acid was complete. In others, when the food was not capable of an acid transformation, it remained neutral to the last. In no case did any part of the food pass through the peculiar changes of chymification. More recently, MM. Bouchardat and Sandras,[1] from the results of a series of experiments instituted by them, believe they have established, that stomachal digestion and the movements of the organ are interrupted by the simultaneous section of both pneumogastrics on a level with the larynx; and farther, that intestinal digestion, and the production and absorption of a very laudable chyle persist notwithstanding such section; and M. Longet[2] concludes, that the section of the pneumogastrics seriously affects chymification, chiefly by paralysing the proper movements of the stomach, but partly by diminishing the secretion of the gastric solvent; and lastly, Professor Bérard,[3] after examining the different experiments and inferences of preceding inquirers, infers:—that "the mixed cords of the pneumogastrics and the branches furnished by the great sympathetic to the stomach beneath the diaphragm, contribute to the maintenance of the contractility of the stomach and the secretion of the gastric juice. A greater share, however, ought to be assigned to the cords of the pneumogastric than to the sub-diaphragmatic branches of the great sympathetic. Moreover, the motor influence of the pneumogastric appears to predominate over the secretory; in other words, the resection of the nerve paralyses the movements more than it diminishes the secretion."

Of all these theories of chymification, that of chemical action, aided by the collateral circumstances to be mentioned presently, can alone be embraced; yet, how difficult is it to comprehend, that any one secretion can act upon the immense variety of animal and vegetable substances employed as food! The discovery of the chlorohydric and acetic acids and of pepsin in the secretion, aids us in solving the mystery expressed by the well-known pithy and laconic observation of Dr. William Hunter in his lectures: "Some physiologists will have it, that the stomach is a mill; others, that it is a fermenting vat, others, again, that it is a stewpan;—but, in my view of the matter, it is neither a mill, a fermenting vat, nor a stewpan;—but a stomach, gentlemen, a stomach."

Allusion has been already made to pepsin—an organic compound thrown off from the stomach—which is an active agent in digestion. It had been observed in the experiments of Eberle and Schwann, that

[1] Bouchardat, Annuaire de Thérapeutique, de Matière Médicale, &c., pour 1848, p. 306, Paris, 1848.
[2] Op. cit., p. 340.
[3] Cours de Physiologie, 12e livraison, p. 235, Paris, 1849.

although acids alone have little power in digesting food, they act energetically, when combined with the mucus of the stomach. Eberle thought, that the acidulated mucus of any membrane would produce the effect, but J. Müller and Schwann found it to be restricted to that of the stomach. The agency of pepsin is regarded by Liebig[1] to be similar to that of *diastase* in the germination of seeds. Both are bodies in a state of transformation or decomposition; the latter effecting the solution of starch by its conversion into sugar; and the former the formation of alimentary matter into chyme. The present belief amongst physiologists and chemists—from all these experiments, as well as those of Wasmann and others—is, that pepsin, by inducing a new arrangement of the elementary particles or atoms of alimentary matter, disposes it to dissolve in the gastric acids. Chlorohydric acid, indeed, dissolves white of egg by ebullition, just as it does under the influence of pepsin; so that pepsin replaces the effect of a high temperature in the stomach.[2] Liebig, consequently, does not believe, that the digestive process is a simple solution, but a species of fermentation, not identical, however, with any of the known processes of fermentation occurring in organic matters out of the body. It differs from ordinary fermentation in being unattended with the formation of carbonic acid; in not requiring the presence of oxygen, and in not being accompanied by the reproduction of the ferment.[3]

The conclusions of MM. Bernard de Villefranche and Barreswil,[4] from numerous and varied experiments related to the *Académie Royale des Sciences*, of Paris, have been referred to already. From these, it would seem, that an organic compound of like nature exists in the saliva, gastric juice, and pancreatic fluid; and that its digestive powers vary according as it is associated with fluid having an acid or an alkaline reaction. Thus in the gastric juice, which is acid, it readily dissolves nitrogenized substances,—fibrin, gluten, albumen, &c., whilst it is altogether without action on starch. These gentlemen affirm, that if we destroy this acid reaction, and render the gastric juice alkaline by the addition of carbonate of soda, the active organic matter being in presence of an alkaline fluid changes its physiological action, and becomes able to modify starch rapidly, whilst it loses the power of digesting nitrogenized substances. As the saliva and pancreatic juice are alkaline, it was interesting to know whether a change in the chemical reaction of these fluids would produce in them the same change of properties as in the case of the gastric juice. Experiment proved such to be the fact. By rendering the pancreatic fluid or saliva acid, their ordinary action was inverted: they acquired the power of dissolving meat and other nitrogenized substances, whilst they lost their influence on starch.

M. Magendie examined the gases in the stomach and intestines of executed criminals, and obtained the following results: *a*, in the case of an individual who had taken food in moderation an hour previous to

[1] Animal Chemistry, Gregory and Webster's edit., p. 106, Cambridge, Mass., 1842.
[2] Graham's Elements of Chemistry, Amer. edit., by Dr. Bridges, p. 696, Philad., 1843.
[3] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 173, Philad., 1849.
[4] Comptes Rendus, 9 Decemb., 1844, and 7 Juillet, 1845.

death; *b*, in the case of one who had eaten two hours previously; and *c*, in the case of one who had done so four hours previous to execution.

		100 volumes of the gas contained			
		Oxygen.	Azote.	Carbonic Acid.	Inflammable Gas.
a	From the stomach,	11·00	71·45	14·00	3·55
	——— small intestines,	00·00	20·03	24·39	55·33
	——— large do.	00·00	51·03	43·50	5·47
b	From the stomach,	00·00	00·00	00·00	00·00
	——— small intestines,	00·00	8·85	40·00	51·15
	——— large do.	00·00	18·40	70·00	11·60
c	From the stomach,	00·00	00·00	00·00	00·00
	——— small intestines,	00·00	66·60	25·00	8·40
	——— large do.	00·00	45·96	42·86	11·18[1]

From these results it appears, that when the execution occurred not longer than an hour after a meal, oxygen was found in the stomach; and when not until two hours, it had entirely disappeared, and a large quantity of nitrogen was found in the intestines, with an entire absence of oxygen; whence it is inferred, that the oxygen of the air is separated from the nitrogen in the stomach; and the former is employed in digestion. The view of Liebig is, that the oxygen occasions a molecular action in the pepsin or animal matter in the stomach, and that this intestine motion is communicated to the molecules of the albumen or protein of the food, so that the latter is rendered soluble in the gastric acid.[2] The oxygen he refers to atmospheric air enclosed in the saliva during mastication, and in that way introduced into the stomach.

Researches into the phenomena of digestion, made some years ago by MM. Bouchardat and Sandras,[3] led them to the following conclusions. *First.* The functions of the stomach in digestion consist in dissolving, with the aid of chlorohydric acid, all albuminous matters, as fibrin, albumen, casein, and gluten. *Secondly.* This acid, if diluted with 5000 parts of water, dissolves the same matters out of the body, provided they are not cooked; but if boiled, the solution has no action upon them. As they are found, however, dissolved in the stomach, it is probable that some other agency is at work than simple solution by means of chlorohydric acid; but the presence of that acid appears to be indispensable. *Thirdly.* As far as albuminous matters are concerned, digestion and absorption take place exclusively in the stomach through the veins; the intestines present scarcely any traces of those matters although they exist in such abundance in the stomach. *Fourthly.* Solution of fecula occurs in the stomach. This principle does not appear to pass into the state of sugar; and the experiments did not even warrant the statement, that it passes into that of soluble starch; but they regard its transformation into lactic acid as proved. *Fifthly.* The absorption of this form of aliment appears to take place less exclusively from the stomach than that of albuminous matters,—a circumstance which accords with the special arrangement and length of the intestines of animals not carnivorous. *Sixthly.* Fatty matters are not acted on

[1] Liebig, op. cit., p. 289. [2] Ancell, Lond. Lancet, Dec. 16, 1842, p. 419.
[3] Annales des Sciences Naturelles, Oct., 1842, or Edinb. Med. and Surg. Journal., Jan., 1843.

in the stomach. They proceed into the duodenum forming an emulsion with alkalies furnished by the liver and pancreas. This emulsion is found abundantly throughout the whole course of the intestines. *Seventhly.* The chyle appears somewhat less abundant, but presents similar characters in animals that are killed after long fasting; as in those killed after having taken copious meals of albuminous matters and fecula. In those, however, that had been fed on fatty matters fat was found in it in considerable proportion.

According to those views—which were favourably reported upon to the *Académie Royale des Sciences of Paris*, by MM. Payen, Magendie, Flourens, Milne Edwards and Dumas,[1] and "the authors encouraged to persevere in a study that still presents so many problems for solution, and into which they have but entered, although they have already made some curious observations,"—most articles undergo complete digestion in the stomach; but fat requires an admixture with the secretions poured into the intestines, and is taken up only by the chyliferous vessels. MM. Bouchardat and Sandras do not, however, restrict the agency of those vessels to the absorption of fat. They suggest—and it can only be regarded as a suggestion—that the abdominal glands prepare for the chyliferous vessels and thoracic duct a chyle, the alkaline character of which is in a direct ratio with the acidity developed in the stomach during digestion. This chyle—not obtained from the food but by a true process of secretion—enters the blood through the chyliferous apparatus, to neutralize the acid, that is indispensable for the solution of the food in the stomach to prepare it for absorption from that organ.

Should the views of MM. Bouchardat and Sandras be established, they would modify materially former notions in regard to the physiology of the digestion of solids. It need hardly be said, however, that a succession of repeated and careful experiments tending to the same results will be necessary before they can be regarded as worthy of more than a passing notice. Certain of the positions of these gentlemen have received support from the investigations of M. Blondlot.[2] He is of opinion, that of all the simple alimentary substances, those that are fluid at the ordinary temperature of the stomach, and those that are readily soluble in its secretions, as fluid albumen, sugar, gum, pectin, &c., are at once absorbed by the veins. It would seem, indeed, that in cases of scirrhus of the pylorus, and where a cancerous communication has existed between the stomach and colon,[3] nutritious matter must necessarily be absorbed from the stomach: except, however, in such cases, the view, that digestion can be accomplished by the gastric veins, independently of the action of any gastric secretions, can scarcely be maintained.[4] It would seem, moreover, that certain aliments, after having experienced the necessary stomachal and intestinal changes, are received by imbibition into the veins of the intestines. MM. Bouchardat

[1] Encyclographie des Sciences Médicales, Févr., 1843, p. 159.

[2] Traité Analytique de la Digestion, Paris, 1844.

[3] Such a case is given by Dr. William Waters, in Philadelphia Med. Examiner, p. 201, April, 1845.

[4] A Physiological Essay on Digestion. By Nathan R. Smith, M.D., &c., New York, 1825.

and Sandras affirm, that after herbivorous animals have been fed on farinaceous substances, more dextrin, grape sugar and lactic acid are detected in the blood of the vena porta than in that of any other blood-vessel.[1] Trommer, also, detected grape sugar in the blood of the portal vein, but not in that of the hepatic vein in animals to which that substance had been given with their food.[2] The bearing of such observations on the production of sugar by the liver will be shown hereafter.

In conclusion:—Let us inquire into the various agencies to which the food is exposed during the progress of chymification. *First.* It becomes mixed with the secretions, already existing in the stomach, as well as with those excited by its presence. *Secondly.* It is agitated by the peristaltic motion of the stomach itself, and the movement of the neighbouring organs. *Thirdly.* It is exposed to a temperature of at least 100° of Fahrenheit, which, during the ingestion of food, does not rise higher: exercise elevates, whilst sleep, or rest, or a recumbent posture, depresses it.[3] After food has been subjected to these influences, the conversion into chyme commences. This always takes place from the surface towards the centre: the nearer it lies to the surface of the stomach, the more it is acted on; and the part that is in contact with the lining membrane is more digested than any other;—appearing as if corroded by some chemical substance capable of dissolving it.

Dr. Wilson Philip[4] asserts, that the new food is never mixed with the old; the former being always found in the centre, surrounded on all sides by the latter. If the old and new be of different kinds, the line of separation between them is so evident, that the former may be completely removed without disturbing the latter; and if they be of different colours, the line of demarcation can frequently be distinctly traced through the parietes of the stomach before they are laid open. Dr. Beaumont,[5] however, affirms, that this statement is not correct; that, in a very short time, the food, already in the stomach, and that subsequently eaten, become commingled. In the subject of his experiments, he invariably found that the old and new food, if in the same state of comminution, were readily and speedily combined.

The conversion of the food into chyme, it has been conceived, commences in the splenic portion, is continued in the body of the viscus, and completed in the pyloric portion. On this point, the observations of Dr. Philip differ somewhat from those of M. Magendie,[6] the former appearing to think, that chymification is chiefly accomplished in the splenic portion and middle of the stomach; whilst the latter affirms, that it is mainly in the pyloric portion that chyme is formed;—the alimentary mass appearing to pass into it by little and little, and during its stay there to undergo transformation. He further affirms, that he has frequently seen chymous matter at the surface of the alimentary

[1] Gazette Médicale de Paris, Jan., 1845.
[2] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 191, Philad., 1849.
[3] Beaumont, On the Gastric Juice, p. 274.
[4] Exper. Inquiry, ch. vii. sect. 1; and Treatise on Indigestion, Lond., 1821.
[5] Op. citat., p. 89.
[6] Précis, &c., edit. cit., ii. 88.

mass filling the splenic half; but that it commonly preserves its properties in this part of the organ.

The precise steps of the change into chyme cannot be indicated. Some of the results, at different stages of the process, have been observed on animals; and pathological cases have occasionally occurred, which enabled the physiologist to witness what was going on in the interior of the stomach; but, with perhaps one exception, those opportunities have not been much improved. Dr. Burrows[1] relates a case of fistulous opening into the organ. The subject of the case was not seen by him until twenty-seven years after the injury, at which time the man was, to all appearance, healthy; but he was drunken, and dissipated, and the following year died. A case is related by Schenk;[2] and Louis[3] refers to similar cases that occurred to Foubert and Covillard. Helm, of Vienna,[4] published a case, to which reference has already been made; and one of an interesting character occurred at the Hospital *La Charité* of Paris, which sheds some little light on the subject.[5] The aperture, which was more than an inch and a half long, and an inch broad, exposed the interior of the organ. At the admission of the female into the hospital, she ate three times as much as ordinary persons. Three or four hours after a meal, an irresistible feeling compelled her to remove the dressings from the fistulous opening, so as to allow the escape of food which the stomach could no longer contain,—when the contents came out quickly, accompanied by more or less air. They possessed a faint smell, but had neither acid nor alkaline properties; and the grayish paste, of which they consisted when diluted with distilled water, did not affect vegetable blues. Digestion was far from complete; yet, frequently the odour of wine was destroyed; and bread was reduced to a soft, viscid, thick substance, resembling fibrin recently precipitated by acetous acid, and swimming in a stringy fluid of the colour of common soup. Experiments, made on this half-digested food, at the *Ecole de Médecine*, showed that the changes, which it had undergone, were an increase of gelatin; the formation of a substance like fibrin; and a considerable portion of chloride of sodium, phosphate of soda and phosphate of lime. The patient could never sleep until she had emptied her stomach, and washed it out by drinking infusion of chamomile. In the morning, it contained a small quantity of thick, frothy liquid, analogous to saliva, which did not affect vegetable blues; with matters of greater consistence, and some opaque, albuminous flocculi mingled with the liquid portion. The results of chemical experiments on this liquid were similar to those obtained on the analysis of saliva.

But the most interesting case in its observed phenomena is one that occurred to Dr. Beaumont,[6] of the United States Army, now of Saint Louis, which the author had an opportunity of examining. To this case, reference has already been made repeatedly. A Canadian lad,

[1] Transactions of the Royal Irish Academy, vol. iv.
[2] Observ. Medic. Rar. Nov., &c., lib. iii., Francof., 1609.
[3] Mémoir. de l'Académie Royale de Chirurgie, vol. iv. p. 213, Paris, 1819.
[4] Rudolphi. Grundriss der Physiologie, 2ter Band, 2te Abtheil., s. 114, Berlin, 1828.
[5] Richerand's Elémens de Physiologie, edit. cit., p. 72.
[6] Op. citat., Introduction, p. 10; and the Author's Elements of Hygiène, p. 216, Philad., 1835.

Alexis San Martin, eighteen years of age, received a charge of buckshot in his left side, which carried away integuments and muscles of the size of the hand; fracturing, and removing the anterior half of the sixth rib; fracturing the fifth; lacerating the lower portion of the left lobe of the lung and the diaphragm, and perforating the stomach. When Dr. Beaumont saw the lad, twenty-five or thirty minutes after the accident, he found a portion of the lung, as large as a turkey's egg, protruding through the external wound, lacerated and burnt; and, immediately below this, another protrusion, which, on inspection, proved to be a portion of the stomach, lacerated through all its coats, and suffering the food he had taken at breakfast to escape through an aperture large enough to admit the forefinger. It need scarcely be said, that numerous untoward symptoms occurred in the cicatrization of so formidable a wound. Portions of the ribs exfoliated; abscesses formed to allow the exit of extraneous substances; and the patient was worn down by febrile irritation. Ultimately, however, the care and attention of Dr. Beaumont were crowned with success, and the instinctive actions of the system repaired the extensive injury. The wound was received in 1822, and on the 6th of June, 1823, one year from the date of the accident, the injured parts were sound, and firmly cicatrized, with the exception of the perforation leading into the stomach, which was about two inches and a half in circumference. Until the winter of 1823–4, compresses and bandages were needed to prevent the escape of the food. At this period, a small fold or doubling of the inner coat of the stomach appeared forming at the superior margin of the orifice, slightly protruding, and increasing in size until it filled the aperture. This valvular formation adapted itself to the opening into the organ, so as to completely prevent the escape of the contents, when the stomach was full; but it could be readily depressed by the finger. Since the spring of 1824, San Martin has enjoyed general good health; he is active, athletic, and vigorous; eating and drinking like a healthy individual. From the summer of 1825, Dr. Beaumont had been engaged in the prosecution of numerous experiments upon him; some of the results of which he has given to the world. In the winter of 1833, he was in Washington, when the author—at the time, Professor of Medicine in the University of Virginia—was politely invited to examine him for physiological purposes. Many of the results of this examination are given by Dr. Beaumont, and have already been, or will be, referred to in the present work. Dr. Beaumont's researches into the comparative digestibility of different alimentary substances belong to another department of medical science, and have accordingly received attention from the author elsewhere.

What, then, it may be asked, are the changes wrought on the food in the stomach by the gastric secretions? Dr. Prout[1] classes them under three operations;—the *reducing*, *converting*, and *organizing* and *vitalizing*. The first of these is probably the main operation. In order to decide, whether the action of the stomach in digestion be a simple solution, or a total or partial conversion, certain compounds of organization, easy of detection—as *gelatin*, *albumen*, and *fibrin*—were introduced,

[1] Bridgewater Treatise, Amer. edit., p. 235, Philad., 1834.

at the author's suggestion, into the stomach through the fistulous opening in the subject of Dr. Beaumont's case; whilst other portions were digested *artificially* in gastric juice obtained from the same individual. The solutions presented the same appearance, and were similarly affected by reagents; and in all cases, whether the digestion was *artificial* or *real*, the proximate principles could be thrown down in the state of *gelatin*, *fibrin* or *albumen*, as the case might be. These experiments, so far as they go, justify the conclusion, that the digestive process in the stomach is a simple solution or division of alimentary substances, and an admixture with the mucous secretions of that organ, and the various fluids from the supra-diaphragmatic portion of the digestive tube. With regard to the existence of the other gastric operations described by Dr. Prout, well-founded doubts may be entertained. To his proposition that, whatever may be the nature of the food, the general composition and character of the chyle remain always the same, no objection can be urged; but, admitting its accuracy, it by no means follows, that the conversion must be effected in the stomach, or that any organizing or vitalizing powers are exerted upon the chyme in that organ. On the contrary, it appears to us, that the essential changes effected on solid aliment in the stomach are of a purely physical character, so as to adapt it for the separation of the chylous portion in the intestines by organs whose vital endowments and influences cannot be contested. Dr. T. J. Todd[1] is disposed to believe, from his experiments on artificial digestion, that the various vegetable and animal substances subjected to the action of the digestive fluids at the ordinary temperature of the atmosphere are, in all instances, reduced—not to their *chymical*, but to their *organic* elements; and he is of opinion, that this applies equally to digestion in the stomach.

From what has been already shown of the close approximation to each other in chemical composition of several of the compounds of organization, it may be understood, that many vegetable principles might be converted into animal principles without any material change of composition. They might all perhaps be changed into albumen, from which, as elsewhere seen, fibrin differs but little except in its organizable power. Saccharine matters—it has been conceived—may be converted, in the digestive tube, partly into albumen, and partly into oleaginous matter, the nitrogen of the former being furnished, according to some, by the pepsin or by some highly nitrogenized substance secreted in the stomach or duodenum or both;[2] but whether such conversion really occurs is exceedingly questionable. The oleaginous matters themselves are absorbed by simple imbibition as an emulsion formed by their union with the alkali of the pancreatic fluid.[3]

On the whole, in the present state of our knowledge of this important function, we are perhaps justified in concluding:—*First.* That by the operation of the gastric secretions the nitrogenized principles of the food, whether animal or vegetable, are dissolved in the stomach. *Se-*

[1] Brit. Annals of Medicine, Jan., 1837.

[2] Prout, on the Stomach and Urinary Diseases, p. xxviii., note.

[3] Matteucci, Lectures on the Physical Phenomena of Living Beings, by Pereira, Amer. edit., p. 110, Philad., 1848, and C. Bernard, Archives Générales, xix. 60, cited in British and Foreign Medico-Chirurgical Review, p. 528, April, 1849.

condly. That amylaceous matters are converted into saccharine, and these last are absorbed; or they undergo a farther change, by which they are partly converted into lactic acid, and partly into oleaginous matter, and are absorbed in one of these states. *Thirdly*. That the oleaginous principles are either formed into an emulsion or absorbed without alteration; and *Fourthly*. That with the exception of certain mineral substances, matters that cannot be reduced to either of these forms are rejected as excrement.

In proportion as the food is digested, it passes through the pylorus. After the layer, that lies next to the mucous membrane, has experienced the requisite change, and is propelled onwards by the muscular action of the organ, the portion lying next to it becomes subjected to the same process. The gastric fluid, at the same time, penetrates, in a greater or less degree, the entire alimentary mass, so that, when the central portion comes in contact with the surface of the stomach, its conversion is already somewhat advanced. The chyme, thus successively formed, does not remain in that organ, until the whole alimentary mass has undergone chymification; but as it is completed, it is transmitted, by the peristaltic action, through the pylorus into the duodenum. In the early stages of digestion, the passage of the chyme from the stomach is more slow than in the later. At first, it is more mixed with the undigested portions of food, and, as Dr. Beaumont[1] suggests, is probably separated with difficulty by the powers of the stomach. In the more advanced stages, as the whole mass becomes chymified, the process is more rapid, and is accelerated by the peculiar contraction of the stomach, already described. After the expulsion of the last particles of chyme, the organ becomes quiescent, and no more gastric secretion takes place, until a fresh supply of food is received, or some mechanical irritation is produced in its inner coat.

The time, required for the complete chymification of a meal, is stated by the generality of physiologists to be about four or five hours. In Dr. Beaumont's case,[2] a moderate meal of meat, with bread, &c., was digested in from three hours to three hours and a half. We believe that, in by far the majority of cases, a longer time than this is necessary; and in laborious digestions, the presence of food can be distinguished by eructations for more than double the time. It is manifest, that no fixed period can be established for the production of this effect. It must vary, according to the digestive capability of the individual; the state of his general health; and the relative digestibility of the aliments employed; all which, as we have already seen, admit of great diversity.

During chymification, only a very small quantity of air is found in the stomach; sometimes, none. When met with, it is near the cardiac orifice, or at the upper part of the splenic portion. The experiments of M. Magendie, on this point, have been referred to. The small quantity of air, discovered in the stomachs of animals, disproves the idea of M. Chaussier, that we swallow a bubble at each effort of deglutition. If so, the stomach ought to be always inflated, especially after eating,

[1] On the Gastric Juice, p. 96. [2] Ibid., p. 275.

which is not the case. MM. Leuret and Lassaigne[1] found the air, obtained from the stomach of a dog fed on meat, to consist of carbonic acid, 43 parts; sulphuretted hydrogen, 2 parts; oxygen, 4 parts; nitrogen, 31 parts; carburetted hydrogen, 20 parts. Whence these gases proceed will be a subject of future inquiry.

In a robust individual, chymification is effected without consciousness of the process. He finds, especially if the stomach be over-distended, that the feeling of fulness and the oppression of respiration, produced by the distension of the organ, gradually disappear. It is not uncommon, however, for slight shivering or chilliness to be felt at this time; for the sensations, and mental and moral manifestations to be blunted; and a disposition to sleep to be experienced. "This concentration of the whole vital activity," according to M. Adelon,[2] "is so natural to the animal economy, that there is always danger in opposing or crossing it by any extraneous or organic influence; as by bathing, the use of medicine, violent exercise, mental emotions, intense intellectual effort, &c." Gentle exercise, however, would seem to favour digestion. Such is the conviction of Dr. Beaumont,[3] from his observations. In the subject of his experiment, he found the temperature of the stomach generally raised by it a degree and a half; and chymification expedited. Where digestion is imperfect, the signs, already mentioned, will be accompanied by the disengagement of air and consequent eructations; a sense of weight, or heat, or of unusual distension in the epigastric region, &c.; but these, as well as the developement of sulphuretted hydrogen, discharged by eructation, are the products of ordinary decomposition or fermentation, and appertain to the morbid condition of the function or to indigestion. Yet, as M. Magendie[4] has remarked, it does not seem, that these laborious digestions are much less profitable than others. The food, habitually received into the stomach, contains far more nutritive matter than is necessary to supply the wants of the system; and, in the cases in question, enough chyle is always separated in the small intestine to supply the losses, and even to add to the bulk of the body.

It has been already remarked, that the chyme, first formed, does not continue in the stomach until the whole meal has undergone chymification; but that, as soon as it has experienced the necessary changes, it passes through the pylorus into the duodenum. It would appear, that the accumulation of chyme in the pyloric portion of the stomach never exceeds four ounces at any one time. M. Magendie states, that, in the numerous experiments, in which he has had an opportunity of noticing it, he uniformly found, when the quantity amounted to about two or three ounces, it was permitted to pass through the pylorus into the duodenum. This passage of the chyme is effected by the peristaltic action. At the commencement of digestion, the duodenum contracts inversely, and the pyloric portion of the stomach, at the same time, drives its contents into the splenic. This movement is, however, soon followed by one in an opposite direction; and, after a time, the inverted action ceases,

[1] Recherches sur la Digestion, Paris, 1825.
[2] Physiologie de l'Homme, edit. cit., ii. 433.
[3] On the Gastric Juice, p. 93.
[4] Précis, &c., ii. 104.

and the movement is altogether in one direction;—from the stomach towards the intestine. The movement by which the chyme is immediately sent into the duodenum, is thus effected:—the longitudinal fibres, which pass from the cardiac to the pyloric orifice, contract, and approximate the two orifices; the pyloric portion then contracts, not so as to direct the chyme into the splenic portion, but towards the duodenum: in this manner, the chyme passes from the stomach: and, as fresh portions are formed, they are successively sent onwards; the peristaltic action becoming more and more marked and frequent, and extending over a larger portion of the organ, as chymification approaches its termination. As the chyme is discharged into the small intestine, the stomach gradually returns to its former dimensions and situation.

f. *Action of the Small Intestine.*

The changes in the alimentary mass in the small intestine, are not less important than those already considered. They consist in a farther change of the chyme into a substance, whence *chyle* can be extracted by the action of the chyliferous vessels or lacteals. Whether chyle be separated in the intestine, in a state fit for chyliferous absorption, or be formed by those vessels, will have to be canvassed hereafter. In common language, however, it is said to be separated there, and the process, by which this is accomplished, is called *chylification.*

As the chyme proceeds into the duodenum, it readily finds space, until towards the end of chymification, when the intestine not unfrequently experiences considerable dilatation. The presence of the alimentary mass augments the secretion from the mucous membrane; and occasions a greater flow of the biliary and pancreatic juices. MM. Leuret and Lassaigne[1] found, when they applied vinegar, diluted with water, to the external surface of the small intestine in a living animal, that a considerable quantity of serous fluid was immediately exhaled. The same application, made to the follicles of the intestine, excited the secretion of a greater quantity of mucus; and its application to the mouths of the choledoch and pancreatic ducts caused the orifices to dilate, and a greater discharge of bile and pancreatic juice. It is in this local manner that many of the cholagogue purgatives produce their effect. Calomel exerts its agency on the upper part of the intestinal canal more especially; and the irritation it induces in the mucous membrane at the mouth of the ductus communis choledochus is propagated along the biliary ducts to the liver, the secretion of which is thus augmented,—but not by any specific action exerted on the organ, as has been often imagined. As the chyme is acid, it induces the same effects on the follicles as the acid employed in the experiments of MM. Leuret and Lassaigne.

The chyme does not remain so long in the intestine as food does in the stomach. The successive arrival of fresh portions propels the first onwards; and the same effect is induced by the peristaltic action of the intestines,—an involuntary, muscular movement of an irregular, undulatory, oscillatory or vermicular character, which consists in an

[1] Recherches sur la Digestion, Paris, 1825.

alternate contraction and dilatation of the organ, proceeding generally from above to below, so as to propel the chyme downwards. When it reaches any point of the intestine, its contact excites the contraction of the circular fibres of the part; so that it is sent forwards to another portion of the canal; the circular fibres of which contract, whilst the former are relaxed; and this occurs successively through the whole tract of the intestines. The longitudinal fibres, by their contraction, shorten the intestine, and in this manner meet the chyme, so as to facilitate its progress; but their effect cannot be considerable. When digestion is not going on, the peristaltic action occurs only at intervals; always slowly and irregularly; and, perhaps, as has been suggested, only when sufficient mucous secretion has collected on the inner coat of the intestine to provoke it. During digestion, it is much more energetic and frequent, and more marked in the duodenum and small intestine than in the large; occurring not continuously, but at intervals, as the chyme arrives and excites it. When the small intestine is surcharged, it may take place in several parts of the canal at once; and, at times, the action is inverted.

The secretions poured into the intestinal canal lubricate it, and facilitate the progress of the chyme. This is aided by the free and floating condition of the intestine; and by the agitation of the diaphragm and abdominal muscles in respiration. Yet its course along the small intestine is slow. The chyme is not transmitted from the stomach continuously; and the peristaltic action of the intestines occurs only at intervals. Moreover, owing to the convolutions of the intestinal canal, the chyme must, in many cases, proceed against its own gravity; and be retarded by the numerous valvulæ conniventes, which bury themselves in it, when the canal is contracted by the action of the circular fibres. All these circumstances must cause it to proceed slowly along this part of the tube,—a point of some importance, when we reflect, that an essential change is effected on it through the influence chiefly of the bile and pancreatic juice, and that its nutritive portion is here absorbed. In the duodenum, the course of the chyme is slow. In the jejunum it is more rapid, hence the name, which indicates, that it is almost always found "empty:" in the ileum again it is slower on account of the greater consistence acquired by the absorption of the chylous portion. Whilst the food is in progress along the small intestine, it experiences the change in its physical properties, which enables the chyle to be separated from it by absorption. These two actions have been termed respectively *chylification* and *the absorption of chyle;* although by some the former term has been applied to both processes.

Above the point, at which the common choledoch and pancreatic ducts open into the duodenum, no change is observable in the chyme. It preserves its colour, semi-fluid consistence, sour smell, and slightly acid taste; having been simply mixed with the exhaled and follicular secretions of the lining membrane; but, immediately after it has passed the part, at which the hepatic and cystic bile and the pancreatic juice are poured into the intestine, it assumes a different appearance; its colour is found to be changed; it becomes yellowish; of a bitter taste; its sour smell diminishes; and chyle can now be separated by the lac-

teals. Accordingly, at this part of the canal, chyliferous vessels are first perceptible.

The change effected upon the chyme in the small intestine is probably,—like that produced on the food in the stomach,—of an entirely physical character. The chyle itself, we shall endeavour to show hereafter, is formed by an action of elaboration and selection exerted by the chyliferous vessels. No difference is observable between the chylous and excrementitious portion of the chyme in any part of the small intestine; nor can it be separated by pressure or by any other physical process. M. Magendie,[1] indeed, has affirmed, that if the chyme proceeds from animal or vegetable substances that contain fat or oil, irregular filaments are observed to form, here and there, on the surface,—sometimes of a flat, at others, of a round shape,—which speedily attach themselves to the surface of the valvulæ, and appear to be *brute chyle;* but this is not observed when the chyle proceeds from food, that does not contain fat. In this case, a grayish layer, of greater or less thickness, adheres to the mucous membrane, and appears to contain the elements of chyle. MM. Leuret and Lassaigne[2] state, that if an animal be opened while digestion is going on,—on the surface of the chyme, between the pylorus and the orifice of the ductus communis choledochus, a grayish-white, homogeneous, dense, fluid, and acid substance is perceived on the villi of the intestine. Neither of these, however, is *chyle.* It is merely the substance whence chyle is obtained by the action of the chyliferous vessels. The fact, mentioned by M. Magendie,—regarding the appearance of irregular filaments, when animal or vegetable substances, containing fat or oil, have been taken as diet,—has been the occasion of other erroneous deductions of a pathological character. Frank[3] asserts, that he was requested to see a prince, who was attacked with epilepsy. His physician,—a respectable old practitioner,—assured Frank, that he could make his patient void thousands of filiform worms at pleasure. As he was unable to define either the genus or species of these worms,—the quantity of which, from his account, seemed to be prodigious,—Frank requested to be a witness of the phenomenon. The physician administered a dose of castor oil, which produced numerous evacuations, containing thousands of whitish filaments similar to small eels; but on an attentive examination of these pretended worms, they were found to consist entirely of the castor oil, in a state of fine division.

The alteration of the aliment in the small intestine is probably of a chemical nature; yet its essence is impenetrable. It has, accordingly, been conceived to be organic and vital. The same remarks are applicable here as were indulged upon the supposed organic and vital action of the stomach exerted in the formation of chyme. The agents of this conversion are:—the fluids secreted from the mucous membrane of the small intestine, and the biliary and pancreatic juices, aided by the temperature of the parts, and the peristole. Haller[4] was of opinion, that the first of these is a principal agent. Reflecting on the extensive

[1] Précis, &c., ii. 111.
[2] Op. citat.
[3] De Curandis Hominum Morbis Epitome, lib. vi. p. 218.
[4] Element. Physiol., xix. 5.

surface of the small intestine, on the number of arteries distributed to the organ, and on the size of these arteries, he asserted, that the lining membrane of the intestine, at the time of chylification, secretes a juice, which he estimated at the enormous quantity of eight pounds in the twenty-four hours. To this he gave the name *succus intestinalis*, and assigned it as important a part in chylification as he attributed to the gastric juice in chymification. It is probable, however, that the fluids secreted by the mucous membrane of this portion of the canal resemble those of the rest of the intestinal mucous membrane; and that their main function is that of lubricating the intestine, and of still further diluting the chymous mass. MM. Leuret and Lassaigne endeavoured to procure some of them by making animals, whilst fasting, swallow small sponges, enveloped in fine linen, and killing them twenty-four hours afterwards. Some of these sponges had not gone further than the stomach, and were filled with gastric juice; others, which had reached the small intestine, had imbibed the *succus intestinalis*, which was more yellow, and manifestly less acid than the gastric secretion. On attempting to dissolve a crumb of bread in each of these juices, they discovered that the gastric secretion communicated a sour smell to the bread; but that the intestinal secretion allowed the bread to be precipitated, and dissolved no part of it. From this experiment, it has been concluded, that the succus intestinalis is not a great agent in chylification. The deduction is probably correct; but no weight can be placed upon results obtained in so unsatisfactory a manner; for it is obvious, that no certainty could exist as to the identity between the gastric and intestinal juices and the fluids found in the respective sponges.

We have strong reason for believing, that, even if food should escape the action of the stomach, it is capable of being digested in the small intestine. This may be owing to some of the true gastric juice passing into the intestinal canal, and impregnating it; or it may be a similar secretion from follicles seated there. The lining membrane of the small intestine possesses the property of coagulating milk; and pathological cases occur in which the stomach is, to all appearance, completely disorganized; yet patients survive so long as to compel us to presume, that digestion must have been effected elsewhere than in that organ. M. Magendie[1] placed a piece of raw meat in the duodenum of a healthy dog. At the expiration of an hour it had reached the rectum, and its weight was found to be but slightly diminished; the only change appeared to be at its surface, which was discoloured. In another experiment, he fixed a piece of muscle with a thread, so that it could not pass out of the small intestine. Three hours afterwards, the animal was opened. The piece of meat had lost about half its weight. The fibrin was especially attacked; and what had resisted, which was almost all areolar tissue, was extremely fetid. In experiments by M. Voisin,[2] aliment was introduced into the small intestines of animals,—in one case masticated and mixed with saliva; in another without any preparation. In a few hours, in the first instance, and after a longer period in

[1] Précis, &c., ii. 113. [2] Nouvel Aperçu sur la Physiologie du Foie, etc., Paris, 1833.

the second, the food was as completely chymified as if the process had taken place in the stomach. The same experiments were repeated upon animals whose pylorus had been secured by ligature, and with similar results. One of them lived for a month after the ligature, nourished for that period by food introduced into the duodenum. These facts sufficiently show, that a solvent action is exerted in the small intestine.

The biliary and pancreatic juices are usually esteemed great agents in chylification. It has been already remarked, that the chyliferous vessels do not begin to appear above the part at which these juices are poured into the duodenum; that in the rest of the small intestine they are less and less numerous as we recede from the duodenum; and that the chyme does not exhibit any marked change in its properties, until after its admixture with those fluids. Direct experiments have been made for the purpose of testing the use of the bile in digestion. Sir Benjamin Brodie tied the ductus communis choledochus in young cats, so as to prevent both hepatic and cystic bile from reaching the intestine. He found, that chylification was interrupted, and there were neither traces of chyle in the intestines nor in the chyliferous vessels. The former contained only chyme, similar to that of the stomach, which became solid at the termination of the ileum; and the latter, a transparent fluid, which appeared to be a mixture of lymph, and of the more liquid portion of the chyme. Mr. Mayo,[1] likewise, found, that when the ductus communis choledochus was tied in the cat or dog, and the animals were killed at various intervals after eating, there was no trace whatever of chyle in the lacteals. M. Magendie,[2] however, repeated these experiments on adult animals, and with dissimilar results. The greater part died of the consequences of opening the abdomen, and of the operation required for tying the duct. But in two cases, in which they survived some days, he discovered that digestion had persisted; white chyle had been formed, and stercoraceous matter produced. This last had not the usual colour; but this, as he remarks, is not surprising, as it contained no bile. The experiment was repeated by MM. Leuret and Lassaigne,[3] and with results similar to those obtained by M. Magendie. In the duodenum and jejunum, a whitish chyme adhered to the parietes of the organ; and in the thoracic duct there was a fluid of a rosy-yellow colour, which afforded, on analysis, the same constituents as chyle; although the subjects of the operation had been kept, for some time, without food.

The experiments of Messrs. Tiedemann and Gmelin[4] on this subject were marked by the usual care and accuracy of those observers. They found, that the animals were attacked with vomiting, soon after the operation, and afterwards with thirst and aversion for food; on the second or third day, the conjunctiva became yellow, the evacuations chalky, and very fetid, and the urine yellow. Some of the animals died; others were killed: of the latter, some had previously recovered from the jaundice, owing to a singular recuperative phenomenon, noticed

[1] Lond. Med. and Physical Journal, Oct., 1826; and Outlines of Physiology, 4th edit., p. 125, London, 1837.
[2] Op. citat., ii. 117.
[3] Recherches sur la Digestion, p. 147, Paris, 1825.
[4] Recherches Expérimentales, &c., sur la Digestion, ii. 53, Paris, 1827.

by Dr. Blundell[1] and Sir B. Brodie in their experiments—to the re-establishment of the choledoch duct, by the effusion of lymph around the tied part, and the subsequent dropping off of the ligature. Like Sir B. Brodie, Mayo, Leuret and Lassaigne, and Voisin, they observed that chymification went on as in the sound animal.

The thoracic duct and chyliferous vessels, in animals fed a short time before death, always contained an abundant fluid, which was generally of a yellowish colour. It coagulated like ordinary chyle; the crassamentum acquired the usual red colour; and the only difference between it and the chyle of a sound animal was, that after tying the duct it was never white. They conceived the reason of the difference to be, that the white colour is owing to fatty matter taken up from the food by the agency of the bile, which possesses the power of dissolving fat; and may probably, therefore, aid in effecting its solution in the chyle in the radicles of the chyliferous vessels. Sir Benjamin Brodie and Mr. Mayo are considered to have been misled by the absence of the white colour, usually possessed by the chyle, but which is wanting in ordinary digestion, if the food does not contain fatty matter.[2] The experiments of Dr. Beaumont showed, that oil undergoes but little change in the stomach, and that bile is probably necessary to give it the requisite physical constitution, in order that chyle may be separated from it. Messrs. Tiedemann and Gmelin restrict the agency of the bile in chylification to the accomplishing of the solution of the fatty matter, and to the nitrogenizing or animalizing of food that does not contain nitrogen. The experiments of M. Voisin equally show, that the ligature of the choledoch duct does not prevent the formation of chyle, provided the passage of the pancreatic fluid is not at the same time prevented. In a number of dogs, a ligature was applied so as to completely prevent the passage of bile into the intestine. Two lived three months after the experiment; three, six weeks; and five died shortly after the application of the ligature. In no instance did death appear to be owing to the suspension of digestion or assimilation. Almost all the animals had begun to eat; and, in the majority, food perfectly chymified was found in the duodenum; and well elaborated chyle in the chyliferous vessels. It would appear, therefore, that the bile, although an important, is not an essential agent in digestion in the duodenum. This is signally corroborated by the cases of two infants, four or five months old, recorded by Dr. Blundell. The hepatic ducts in both cases terminated blindly, so that no bile entered the intestines; the evacuations were white like spermaceti, and the skin jaundiced. Yet they grew rapidly, and throve tolerably.

No certain knowledge exists, whether any of the elements of the bile are absorbed in the form of chyle; or whether it acts mainly as a precipitate, and is thrown off with the excrement. As elsewhere shown, however, it is largely excrementitious or depurative.

As to the mode in which the biliary and pancreatic fluids act on the

[1] Researches, Physiological and Pathological, London, 1825; and Elliotson's Physiology, p. 124, London, 1840.

[2] Edinb. Med. and Surg. Journal, xciii.; and Mayo, Outlines of Human Physiology, 4th edit., p. 139, London, 1837.

chyme, we have not had, until recently, much more than conjectures to guide us. MM. Tiedemann and Gmelin suggest, that the soda of the bile unites with the chlorohydric and acetic acids of the chyme; and simultaneously the latter precipitates the mucus of the bile and its colouring principle and resin, which are evacuated with the excrements. The majority of physiologists believe, that bile is divided into two parts, by the action of the chyme; the one—containing the alkali, salts, and a part of the animal matter—uniting with the chyle; the other—containing the coagulated albumen, the coloured, concrete, acrid, and bitter oil—uniting with the fæces, to be discharged along with them. According to this view, the action of the bile would be purely chemical; a part would be recrementitial or taken up again; and a part excrementitial, giving to the excrements their smell and colour; and, according to some, the necessary stimulating property for exciting the flow of the intestinal fluids, and soliciting the peristaltic action of the intestines so as to produce their evacuation. It is more than doubtful, however, whether the bile have any such influence as the last. It is a law in the economy, that no secretion irritates the part over which it passes, or is naturally destined to pass, unless such part is in a morbid condition; and were it otherwise, the mucous membrane of the intestine would be soon accustomed to the stimulation; and, the effect be null. MM. Tiedemann and Gmelin further suggest, that from the abundance of highly nitrogenized principles, which the bile contains, it probably contributes to animalize those articles of food, that do not contain nitrogen; and that it may tend to prevent the putrefaction of the food in its course through the intestines, inasmuch as when it is prevented from flowing into them, their contents appear much farther advanced in decay than in the healthy state. It has been held of late, that bile has the power of transforming saccharine aliments into fat; a circumstance, which is favoured by the discovery of H. Meckel,[1] that when sugar is mixed with bile out of the body a part of it is converted into fatty matter. Admixture with the pancreatic juice would then render its absorption easy. (See SECRETION OF BILE.)

We were not instructed until of late in regard to the precise uses of the pancreatic juice; although many have been assigned to it, which being founded in ignorance of its nature and properties, it would be a waste of time to notice. Messrs. Tiedemann and Gmelin affirm, that it yields to the chyme the richly nitrogenized principles, that enter into its composition; and, consequently, aids in assimilation. In testimony of this, they remark, that the pancreas is larger in herbivorous than in carnivorous animals; and that, in proportion as the chymous matter proceeds along the intestinal canal, it exhibits itself less rich in albumen and other nitrogenized matters, which have probably been abstracted from it by absorption. Dr. Marcet[2] discovered in the chyme of the small intestine a notable development of albumen, which was first perceptible a few inches from the pylorus, and did not exist in the large intestine; and Messrs. Tiedemann and Gmelin found in the intestinal contents of

[1] Henle und Pfeufer, Zeitschrift fur rationelle Medicin; cited by Mr. Paget in Report in British and Foreign Medical Review, p. 261, July, 1846.
[2] Medico-Chirurgical Trans., vi. 618.

animals, that had swallowed pebbles while fasting, more albumen than the pancreatic juice could account for. If such be the fact, albumen must be either developed from the food, or secreted from the mucous membrane.

There is a striking resemblance in chemical properties between the pancreatic juice and saliva; and the views applicable to both one and the other, embraced, as the result of numerous experiments by MM. Bernard and Barreswil, have been already stated. The recent experiments of M. C. Bernard[1] have shed important light on this matter. Exposure of fatty bodies to the pancreatic juice out of the body produced at once a complete emulsion, and resolved them into glycerin and fatty acid;—in the case of butter, butyric acid; whilst no such effect was produced on such bodies by admixture with other fluids—saliva, gastric juice, or serum of the blood, for example. These experiments were frequently repeated with like results in the presence of distinguished observers—MM. Magendie, Bérard, Andral, &c. When dogs to which fatty substances had been given were killed during digestion, these substances were found unaltered until they came in contact with the pancreatic fluid; and if the duct of the pancreas was tied all change was prevented. It would seem, therefore, that although the pancreatic fluid resembles the saliva in many respects—so much so, indeed, that the pancreas has been styled "the abdominal salivary gland,"—it is possessed of properties as a digestive fluid which the saliva has not. In a remark upon a subsequent mémoire by M. Bernard—the commission, consisting of MM. Magendie, Milne Edwards and Dumas—do not hesitate to conclude, that M. Bernard has completely established the physiological office of the pancreas and made known the mechanism of the digestion of fatty matters.[2]

The influence of the temperature of the interior of the intestine, and of the peristaltic motion, on chylification, can be looked upon as only accessory and indirect.

Whilst the chyme is passing through the small intestine, it is subjected to the action of the chyliferous vessels, which extract from it the nutritious part or *chyle*,—the fluid especially destined for the renovation of the blood. How this is accomplished will be treated of under the head of Absorption. In proportion as this absorption is effected, the chyme changes its properties. In the commencement of the jejunum, it is the same as in the duodenum; but, lower down, the grayish layer, that existed at its surface, is observed to gradually disappear. It assumes greater consistence; its yellow colour becomes more marked; and, in the ileum, it has a greenish or brownish tint; and from being acid becomes alkaline, until, at the lower part of the small intestine, it seems to be the useless residue of the alimentary matter, and the various secretions from the upper portion of the digestive apparatus. It is now mere excrementitious matter or fæces, although not possessing the entire fecal odour. Its alkaline character has generally been ascribed to admixture with the bile, pancreatic fluid, and the secre-

[1] Archives Générales, xiv.; translated in the Provincial Medical and Surgical Journal for March 31, 1849.
[2] Gazette Médicale, No. 9, Paris, 1849.

tion from the intestinal glandulæ. The agency of the bile was supposed to be through its free soda, or the carbonate or tribasic phosphate of soda. The bile, however, as shown elsewhere, is neutral; and accordingly it has been suggested as more probable, that the chyme is made alkaline by the ammonia, which is one of the products of the spontaneous decomposition of bile in the intestines.[1] The pancreatic juice is certainly also alkaline.

During the formation of chyle, gases are almost always present in the small intestine. They were first examined by Jurine; but chemical analysis was by no means as advanced at that day as it is now; MM. Magendie[2] and Chevreul have more recently analyzed those, which they found in the small intestines of three criminals; all young and vigorous. The results of this analysis have been given already (p. 599). The gases might originate in various ways. They might pass, for example, from the stomach with the chyme. There is this objection, however, to the view; that the air in the stomach contains oxygen and very little hydrogen; whilst a considerable quantity of the latter gas is almost always found in the small intestine, and never oxygen. Again, they might be secreted by the mucous membrane of the intestine. So far as we know, however, carbonic acid and nitrogen are alone exhaled from the tissues. We would still have to account for the hydrogen. Lastly, they might arise from the reaction of the elements of the chyme upon each other, and this has been considered the most probable origin. M. Magendie[3] has frequently seen bubbles of gas escaping from the chymous mass, between the mouth of the ductus communis choledochus and the ileum; but never from that of the ileum, the upper part of the duodenum, or stomach; and he affirms, that Chevreul, in prosecuting some experiments, found that when the mass obtained from the small intestine was suffered to ferment for some time in a stove, at the temperature of the body, the same gases were obtained as those met with in the small intestine.

When the food has attained the lower part of the ileum, the process of chylification has been accomplished, and the residuary matter is transmitted, by the peristaltic action, into the large intestine. The movement, however, recurs irregularly and at long intervals. In the living animal it can rarely be perceived; but may be noticed in one recently killed, and appears to have no coincidence with that of the pylorus.

g. *Action of the Large Intestine.*

The large intestine acts as a reservoir and excretory canal for the fæces. The residue of the alimentary matter is sent on through the valve of Bauhin by the peristaltic action of the ileum. This valve, we have seen, is so situate at the point of union between the ileum and cæcum as to permit a free passage from the former to the latter, but to prevent return. The chymous mass is sufficiently soft to pass readily; and the quantity of mucus poured out from the lining membrane,

[1] Valentin, Lehrbuch der Physiologie des Menschen, i. 338, Braunschweig, 1844.
[2] Précis, ii. 115. [3] Ibid., 117.

facilitates its course. When it has reached the large intestine, it first accumulates in the cæcum, which—being cellular or pouched like the colon—necessarily detains it for some time. In proportion, however, as the cæcum becomes filled, the peristaltic action is extended from the small intestine, and the matter is sent into the colon, the cells of which are successively filled; first, those of the ascending, and then those of the transverse and descending colon, as far as the annulus or commencement of the rectum. The whole of its progress through the large intestine is slowly accomplished. Independently of the pouched arrangement, which retards it, a part of the colon ascends, so that the fæcal matter must often proceed contrary to gravity. It becomes, moreover, more and more inspissated in its progress towards the outlet; and the peristaltic action recurs at greater intervals than in the upper portions of the tube. The importance of such a reservoir as the large intestine is obvious. Without it, we should be subjected to the inconvenience of evacuating the fæces incessantly.

Before the excrementitious matter reaches the lower portion of the small intestine, it has not the fecal odour; but acquires it after having remained there for a short time. The brownish-yellow hue becomes deeper; but its consistence, smell, and colour, vary considerably, according to the character of the alimentary matter; the mode and degree in which chymification and chylification have been accomplished; the habit of the individual, &c. &c. The fæcal matter, as we find it, consists of the excrementitious part of the food, as well as of the juices of the upper part of the canal, that have been subjected to the digestive process; of the secretions, poured out from the lower part of the intestine, and also, of substances, that have escaped the digestive actions of the stomach and small intestine, and are often perceptible in the evacuations. The peculiar fæcal impregnation is probably dependent upon a secretion from appropriate follicles—those of Peyer, for example; and we can thus understand, if we take into consideration the digestion of the different secretions, why fæcal evacuations may exist, when the individual has not eaten for some time, or taken but little nourishment.

Some physiologists have believed, that chylification takes place even in the large intestines, and that chylous absorption is more or less effected there. M. Viridet[1] asserted, that the cæcum is a second stomach, in which a last effort is made to separate from the food the digestible and soluble portions it may still contain. In herbivorous animals, according to him, an acid solvent is secreted in it. MM. Tiedemann and Gmelin seem to admit the fact; and likewise think, that the fluid, secreted by the inner membrane of the intestine, assists in the assimilation of the food by means of the albumen it contains, and that fæcal matter is formed there. From various experiments instituted by Professor Schultz,[2] of Berlin, he infers, that the food in the cæcum becomes not only a second time sour, but that the acid chyme is there neutralized by the access of bile in the same way as in the duo-

[1] Tractatus Novus de Primâ Coctione, &c., Genev., 1691.

[2] Lond. Med. and Surg. Journ., Oct. 31, 1835; cited in Amer. Journal of the Medical Sciences, Nov., 1836, p. 203.

denum. M. Blondlot,[1] however, states, that in many herbivorous animals and granivorous birds, as sheep, goats, pigeons and chickens, the contents of the cæcum were never acid unless sugar in some form had been mixed with their food. The acidity of the cæcum which then ensues, he thinks is the result of that part of the starch or sugar, which has not been absorbed in the small intestine, being transformed into lactic acid. The fact of the separation of chyle in the cæcum and colon is proved by the experiments of M. Voisin,[2] which consisted in introducing food into these intestines after the ileo-cæcal valve had been closed by ligature.

The physical characters of the fæces have been already described. When extruded, they have the shape of the large intestine, or of the aperture, through which they have been evacuated. If the form of either of these be modified, that of the excrement will be so likewise. In stricture of the colon—especially about the sigmoid flexure—and of the rectum, the fæces are squeezed through the narrowed portions, and often evacuated in the shape of ribands. The quantity must, of course, vary according to circumstances, and cannot be rigidly estimated. Approximately, they have been presumed to be, in the adult male, from a quarter to half a pound in the twenty-four hours, the evacuation being usually made once only in this time. The biliary secretion appears to modify the appearance of the fæces greatly. If, as in jaundice, it be prevented from flowing into the intestine, they are clay-coloured. M. Adelon[3] affirms, that, under such circumstances, they are more frequent. This is not the result of our experience, nor does it appear to be deduced from his own; as, a few pages before, he remarks, "it is certain, that if the bile does not flow, the excrements are dry, devoid of colour, and there is constipation." On the other hand, if the bile flows in too great quantity the fæces are darker coloured. It is doubtful, whether the varying quantity of the biliary secretion have much influence on the number of evacuations, unless the canal, through which it has to pass, is in a morbid condition. Many of the appearances in the fæces, which are conceived to be owing to a morbid condition of the biliary secretion, are the effect of admixture with products of morbid changes in the stomach or intestines. In elucidation of this, it may be observed, that the green evacuations of children are often referred to some pathological condition of the biliary secretion; whereas the colour is commonly owing to unusual formation of acid in the stomach, the admixture of which with healthy bile produces the colour in question.

The chemical properties of the fæces have been repeatedly inquired into. They must, of course, vary according to the nature of the food, its quantity, the kind of digestion, &c. Human fæces were examined by Rawitz[4] after animal and vegetable food had been taken. But few fragments of muscular tissue were met with; but the cells of cartilage and fibro-cartilage—excepting those of fish—were found unchanged. Elastic fibres and fatty matters, which had escaped absorption, appeared

[1] Traité Analytique de la Digestion, Paris, 1844.
[2] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833. [3] Op. citat.
[4] Ueber die Einfachen Nahrungsmittel, Breslau, 1846, cited by Kirkes and Paget, Manual of Physiology, Amer. edit., p. 176, Philad., 1849.

to be unchanged; for fat cells were sometimes unaltered in the fæces; and crystals of cholesterin might generally be obtained from them especially after the use of pork fat as diet.

Of vegetable aliments, large quantities of cell membrane were unaltered; and starch cells were commonly deprived of only part of their contents: the green colouring matter—chlorophyll—was unaffected, and the walls of sap vessels and spiral vessels were usually found in large quantities in the fæces,—their contents having been probably removed during digestion.

The fæces differ in each animal species. Those of the herbivora contain less animal matter than those of the carnivora and omnivora; and the agriculturist is well aware, that the excrements of all animals are not equally valuable as manure. The dung of the pigeon is alkaline and caustic; and hence has been employed in tanning for softening skins. The excrement of dogs, that have fed only on bones, is white, and appears to be almost wholly composed of the earthy matter of bone. It has not, however, been examined by modern chemists. This white excrement is the *album græcum*, *cynocoprus*, *spodium Græcorum*, *album canis* or *stercus caninum album*, of the older writers. It was formerly employed as a discutient to the inside of the throat in quinsies, but is now justly discarded.

M. Vauquelin,[1] on comparing the nature and quantity of the earthy parts of the excrements of fowls with those of the food on which they subsisted, arrived at some results that are of interest to the physiologist. He found that a hen devoured, in ten days, 11111·843 grains troy of oats. These contained of phosphate of lime 136·509 grains; and of silica 219·548 grains; in the whole 356·057 grains. During these ten days she laid four eggs, the shells of which contained 98·779 grains of phosphate, and 58·494 grains of carbonate of lime; and she passed 185·266 grains of silica. The fixed parts, thrown out of the system during the time, consisted of:—

Phosphate of lime,	274·305 grains.
Carbonate of lime,	511·911
Silica,	185·266
Given out,	971·482
Taken in,	356·057
Surplus,	615·425

The quantity of fixed matter, therefore, given out of the system in ten days, exceeded the quantity taken in by this last amount.

The phosphate of lime, taken in, amounted to	136·509 grains.
That given out, to	274·305
	137·796

There must, consequently, have been formed 137·796 grains of phosphate of lime, besides 511·911 grains of the carbonate. The inferences, deduced from these experiments, were, that lime, and perhaps also phosphorus, is not a simple substance, but a compound formed of ingredients

[1] Annales de Chimie, tom. xxix. p. 3.

that exist in oats, water, or air; the only substances to which the fowl had access; and that silica must enter into its composition, as a part had disappeared. Before, however, we adopt these conclusions, the experiments ought to be repeated more than once. The chicken should be fed on oats some time before the excrements and shells are subjected to analysis; as the carbonate of lime, and the excess of phosphate detected on analysis, might have proceeded, not only from the food, but from earthy matters previously swallowed. Care should also be taken, that it has no access to any calcareous earth; and we must be certain, that it has not diminished in weight; as, in such case, the earth may have been supplied from its own body. These precautions are the more requisite, seeing, that experiments have shown, that certain birds cannot produce eggs unless they have access to calcareous earth.

There are some very remarkable instances of chemical changes, in mysterious actions, more immediately concerned in the decomposition and renovation of the frame; or, in what has been abstractedly termed—the function of nutrition. Dr. Henry[1] has announced, that the following substances have been satisfactorily proved to exist in healthy urine;—water, free phosphoric acid, phosphate of lime, phosphate of magnesia, fluoric acid, uric acid, benzoic acid, lactic acid, urea, gelatin, albumen, lactate of ammonia, sulphate of potassa, sulphate of soda, fluate of lime, chloride of sodium, phosphate of soda, phosphate of ammonia, sulphur, and silex;—yet we have no proof that these substances are obtained from any other source than the food; and some of them are with difficulty obtained any where. Every one of them is necessary for the constitution of the urine; and many must be formed by a chemical union of their elements under the vital agency. Some are met with in the animal body exclusively. Berzelius[2] found, in 100 parts of human fæces:—water, 73·3; unaltered residue of animal and vegetable substances, 7·0; bile, 0·9; albumen, 0·9; peculiar extractive matter, 2·7; substance, formed of altered bile, resin, animal matter, &c., 14; salts, 1·2. Seventeen parts of these salts contained, of carbonate of soda, 5; chloride of sodium, 4; sulphate of soda, 2; ammoniaco-magnesian phosphate, 2; phosphate of lime, 4. The excrements have likewise been examined by MM. Leuret and Lassaigne, and others; but none of the analyses have shed much light on the physiology of digestion. Analyses of the ashes of firm human fæces by Enderlin[3] yielded the following results:—chloride of sodium and alkaline sulphate, 1·367; tribasic phosphate of soda, 2·633; phosphate of lime, and phosphate of magnesia, 81·372; phosphate of iron, 2·091; sulphate of lime, 4·56; silica, 7·97.

In the large intestine, gases are met with, along with the fæces. These were examined by MM. Magendie[4] and Chevreul in the three criminals already referred to (page 599). The results accord with those of Jurine,[5] obtained long ago, as regards the nature of the gases; but

[1] Elements of Chemistry, 9th edit., ii. 435, Lond., 1823.

[2] Traité de Chimie, trad. par Jourdan et Esslinger, tom. vii., and Simon's Animal Chemistry, Sydenham Society edit., ii. 372, Lond., 1846, or Amer. edit., Philad., 1846.

[3] Annalen der Chemie und Pharmacie, Mars, 1844, cited by Mr. Paget, Brit. and For. Med. Rev., Jan., 1845, p. 277.

[4] Précis, &c., ii. 126.

[5] Mémoir. de la Soc. Royale de Méd., x. 72.

they do not correspond with what he says relating to the carbonic acid; the quantity of which, according to him, goes on decreasing from the stomach to the rectum. The analyses of MM. Magendie and Chevreul show, that the proportion instead of decreasing, increases. Concerning the origin of these gases, the remarks made on those in the small intestine are equally applicable here.

When the fæcal matter has accumulated to the necessary extent in the rectum, its expulsion follows; and to this function the term *defecation* has been assigned. The fæces collect gradually in the large intestine, without any consciousness on the part of the individual. Sooner or later, the desire or want to evacuate them arises. This is usually classed among the internal sensations or desires. It is, however, of a mixed character. It is not always in a ratio with the quantity of fæces as is shown by the fact, that occasionally the intestine is filled without the want arising; and, if they be unusually thin or irritating, the desire is developed, when an extremely small quantity is present,—as in cases of tenesmus. The period, at which the desire returns, is variable, according to the amount and character of the food employed, as well as the habit of the individual. Whilst the generality of persons evacuate the bowels at least once a-day,—and this at a period often regulated by custom,—others pass a week or two without any alvine discharge, and yet may be in perfect health. Nay, some of the collectors of rare cases[1] have affirmed, on the authority of Rhodius, Panarolus, Salmuth, and others, that persons may remain in health, with the bowels moved not oftener than once a month, three months, half a year, two years, and even seven years! Sir Everard Home[2] refers to the case of General Grose, who was in the Dutch service, under the Duke of Cumberland, in the Flanders war; and who for thirty years had no passage through the bowels. General Gage noticed that he ate heartily; but in two hours left the table and rejected his meal. He was healthy, and capable of exercise like other men. Dr. Heberden[3] mentions the case of a person, who had naturally an evacuation once a month only; and another who had twelve evacuations every day during thirty years, and then seven every day for seven years, and grew fat rather than otherwise. A young lady referred to by M. Pouteau,[4] had no evacuation for upwards of eight years; although during the last year she ate abundantly of fruit, and drank coffee, milk, tea, and broth with yolks of eggs; but she had copious greasy sweats;—and many similar extraordinary cases have been recorded by Dr. Chapman[5] of Philadelphia. When the desire to evacuate has once occurred, it generally persists until the fæces are expelled. Sometimes, however, it disappears and recurs at an uncertain interval; and, if again resisted, may become the source of pain, and ultimately command implicit obedience. That the pressure and irritation of the fæces develope the sensation is evidenced by the fact, that the momentary relief experienced at times, when the desire is urgent,

[1] Art. Cas Rares, in Dict. des Sciences Médicales.
[2] Lect. on Comp. Anat., v. 12, Lond., 1828. [3] Commentarii, p. 14.
[4] Œuvres Posthumes, i. 27, Paris, 1783.
[5] Lectures on the more important Diseases of the Thoracic and Abdominal Viscera, p. 294, Philad., 1844.

is usually accompanied by a manifest upward return of the fæcal matters from the sigmoid flexure into the colon.

In evacuating the fæces, the object to be accomplished is,—that the contents of the large intestine shall be pressed upon with a force superior to the resistance presented by the annulus or upper extremity of the contracted rectum, and the muscles of the anus. The contraction of the rectum is generally insufficient to effect this last object, notwithstanding the great thickness of its muscular layer. In cases, however, of irritability of the rectum, the sphincter is incapable of resisting the force developed by the proper muscular fibres of the gut. Under ordinary circumstances, the aid of the diaphragm and abdominal muscles is invoked, and it is chiefly through these muscles, that volition influences the act of defecation,—suspending, deferring, or accelerating it, as the case may be. After a full inspiration, the muscles that close the glottis; and the expiratory muscles,—especially those of the anterior part of the abdomen, contract simultaneously. The air cannot escape from the lungs; the diaphragm is depressed upon the abdominal viscera, and the whole thorax presents a resisting body; so that all the expiratory power of the muscles bears upon the viscera, and presses them against the vertebral column. In this way, considerable force is exerted upon the contents of the colon and rectum; the resistance of the sphincter,—already diminished by the direct exercise of volition,—is surmounted; it yields, and the fæces are extruded. The levator ani and ischio-coccygeus, aided by the transversus perinei muscle, support the anus during the expulsory efforts, and restore it to its place after the efforts have ceased. Whilst *straining* is effected by the diaphragm and abdominal muscles, the longitudinal muscular fibres of the rectum contract, so as to shorten the intestine, and, consequently, the space over which the fæces have to pass. At the same time, the circular fibres contract from above to below, so as to propel the excrement downwards, and to cause the mucous membrane to extrude, and form a ring or *bourrelet*, like that which occurs at the cardiac orifice of the stomach, when the food is passing from the œsophagus into that organ. If this extrusion occurs to a great extent, it constitutes the disease called *prolapsus ani*.

Dr. O'Beirne[1] of Ireland, guided by the following facts and arguments;—that great irritation would be produced in the sphincter ani, and bladder, if the fæces descended readily into the rectum;—that the difficulty experienced in throwing up an injection is inconsistent with the idea of the gut being open, and proves that it is firmly contracted and closed;—that when the surgeon has occasion to pass his finger up the rectum, he rarely encounters either solid or fluid fæces;—that the two sphincter muscles of the anus are weakened in certain diseases, and divided in operations, and yet it rarely happens, that the power of retaining the fæces is destroyed;—that on passing a stomach-tube to the height of half an inch up the rectum, in a number of healthy persons, it was found, that nothing escaped, and that the tube could be

[1] New Views of the Process of Defecation, &c., Dublin, 1833; reprinted in this country, Washington, 1834.

moved about freely in a space, which, on introducing the finger, was ascertained to be the pouch of the rectum; but that from the highest part of the pouch to the upper extremity of the gut—generally a distance of from six or seven to eight inches—it could not be passed upwards without meeting with considerable resistance, and without using a degree of force to mechanically dilate the intestine, which was plainly felt to be so contracted as to leave no cavity for this extent;—that when the instrument reached, in this way, the highest point of the rectum, the resistance to its passage upward was felt to be sensibly increased, until, at length, by using a proportionate degree of pressure, it passed rapidly forward, as if through a ring, into a space in which its extremity could be moved with great freedom, and as instantly a rush of flatus, of fluid fæces, or of both, took place through the tube;—and that in every instance, where the tube presented the least appearance of fæces after being removed, this appearance was confined to that portion which had entered the sigmoid flexure:—guided by these and other facts, Dr. O'Beirne properly concluded, that in the healthy and natural state, all the part of the rectum above its pouch is at all times, with the single exception of a few minutes previous to the evacuation of the bowels, firmly contracted, and perfectly empty, at the same time that the pouch itself, as well as the sigmoid flexure of the colon, is always more or less open, and pervious,—and that the sphincter ani muscles are but subsidiary agents in retaining the fæces. When the fæces are firm, considerable muscular effort is necessary to expel them; but when they are of a softer consistence, the contraction of the rectum is sufficient.

The sphincters—as elsewhere shown—afford examples of reflex action. After sensation and volition are suspended, they contract under direct irritation. Yet, like the respiratory muscles, they are of a mixed character,—partly voluntary and partly involuntary. They are involuntary, but capable of being aided or impeded by a voluntary effort. The state of gentle contraction, in which they constantly are, is evidently dependent upon their connexion with the spinal cord; for the experiments of Dr. Marshall Hall have exhibited, that it ceases, when the connexion is destroyed.

Air, contained in the intestinal canal, readily moves about from place to place, and speedily reaches the rectum by the peristaltic action alone. Its expulsion, however, is commonly accomplished by the aid of the abdominal muscles; when it issues with noise. If discharged by the contraction of the rectum alone, it is generally in silence. Children are extremely subject to flatulence; in the adult it is not so common. Certain kinds of diet favour its production more than others, especially in those of weak digestive powers, of which condition its undue evolution is generally an indication. The leguminous and succulent vegetables in general belong to this class. Where digestion is tardily accomplished, they give occasion to the copious disengagement of gas. Too often, however, the disgusting habit of constantly discharging air streperously from the bowels is encouraged, rather than repressed; and there are persons, who are capable of effecting the act almost as frequently as they attempt it.

The noise, made by the air, as it passes backwards and forwards in the intestinal canal, constitutes the affection called *borborygmus*.

So much for the digestion of solid food. In so delicate and complicated an apparatus, it would seem, that mischief ought more frequently to result from the various heterogeneous substances that are received into the digestive tube. Its resistance, however, to morbific agencies is astonishing. In the Museum of the Boston Society for Medical Improvement[1] an open penknife is preserved, which was swallowed by a child between three and four years of age, and passed from the bowels after the expiration of fifty-one hours; the child, in the meantime, playing about as usual, and not seeming to suffer. The story of the lunatic, under the care of Dr. Fox of Bristol, who swallowed "some inches" of a poker, which came away without any suffering, is regarded as authentic;[2] and there is no question in regard to the authenticity of the case of the sailor recorded by Dr. Marcet,[3] who swallowed a number of clasp knives with impunity, but ultimately fell a victim to his idle temerity,—having swallowed, in the whole, thirty-seven!

5. DIGESTION OF LIQUIDS.

In inquiring into the digestion of liquids, we shall follow the same order as that observed in considering the digestion of solids; but as many of the acts are accomplished in the same manner, it will not be necessary to dwell upon them.

Thirst or the desire for drink is an internal sensation; in its essence resembling that of hunger, although not referred to the same organs. It arises from the necessities of the system; from the constant drain of the fluid portions of the blood; and is instinctive or essentially allied to organization. The sensation differs in different persons, and is rarely alike in the same. Usually, it consists of a feeling of dryness, constriction, and heat in the back part of the mouth, pharynx, œsophagus, and occasionally in the stomach; and, if prolonged, redness and tumefaction of the parts supervene, with a clammy condition of the mucous follicular—and diminution and viscidity of the salivary—secretions. These phenomena are described as being accompanied by restlessness, general heat, injected eyes, disturbed mind, acceleration of the circulation, and short breathing, the mouth being frequently and largely open, so as to admit the air to come in contact with the irritated parts, and thus afford momentary relief.

Thirst is a very common symptom of febrile and inflammatory diseases, in which fluid—especially cold fluid—is desired in consequence of the local relief it affords to the parched and heated membrane of the alimentary canal. It is also developed by extraneous circumstances: as in summer, when the body sustains considerable loss of fluid; as well as in those diseases—dropsy, diabetes, &c.—which produce the same effect. There are many other circumstances, however, that excite it;—

[1] J. B. S. Jackson, A Descriptive Catalogue of the Anatomical Museum of the Boston Society for Medical Improvement, p. 158, Lond., 1847.

[2] Southey, The Doctor, iv. 297, Lond., 1837.

[3] Medico-Chirurgical Transactions, xii. 52, Lond., 1822.

long speaking or singing; certain kinds of diet as the saline and spicy,—and especially the habit, acquired by some, of drinking frequently. Whilst individuals, thus circumstanced, may need several gallons a day to satisfy their wants;—others, who have, by resistance, acquired the habit of using very little liquid, may be enjoying health and not experiencing the slightest inconvenience from the privation of liquid; so completely are we, as regards the character and quantity of our aliment, the creatures of habit. This privation, it is obvious, cannot be absolute or pushed beyond a certain extent. There must always be fluid enough taken to administer to the necessities of the system.

As in the production of all sensations, three acts are required for accomplishing that of thirst;—impression, conduction, and perception. The last, as in every similar case, is effected by the brain; and the second by the nerves passing between the part impressed and that organ. The act of impression—its seat and cause—will alone arrest our attention, and it will be found that we are still less instructed on these points than on the physiology of hunger. Even with regard to the seat of the impression, we are in a state of uncertainty. It appears to be chiefly in the back part of the mouth and fauces; but whether primarily there, or experienced there by sympathy with the condition of the stomach, is by no means clear. The latter opinion, however, appears the more probable. In a remarkable case, published by Dr. Gairdner of Edinburgh, it was found impracticable to allay thirst by merely supplying the mouth, tongue, and fauces with fluid. A man had cut through the œsophagus. An insatiable thirst arose; several pailfuls of water were swallowed daily, and discharged through the wound without removing the desire for drink; but on injecting water, mixed with a little spirit, into the stomach, it was soon quenched. That the sensation is greatly dependent upon the quantity of fluid circulating in the vessels is shown by the fact, mentioned by M. Dupuytren, that he succeeded in allaying the thirst of animals, by injecting milk, whey, water or other fluids into the veins; and M. Orfila states, that, in his toxicological experiments, he frequently allayed in this way the excessive thirst of animals, to which he had administered poison; and which were incapable of drinking, owing to the œsophagus having been tied. He found, also, in his experiments, that the blood of animals was more and more deprived of its watery portions as the abstinence from liquids was more prolonged.[1]

Like all other sensations, that of thirst arises from an inappreciable modification of the nerves of the organ: hence, all the hypotheses proposed to account for it have been mere fantasies undeserving of enumeration.

The *prehension of liquids* differs somewhat from that of solids. The fluid may be simply poured into the mouth, or a vacuum may be formed in it: the pressure of the atmosphere then forces it in. When we *drink* from a vessel, the mouth is applied to the surface of the fluid; the chest is then dilated, so as to diminish the pressure of the atmosphere on the portion of the surface of the liquid intercepted by the

[1] Adelon, Physiologie de l'Homme, 2de édit., ii. 525, Paris, 1829.

lips; and the atmospheric pressure on the surface of the fluid in the vessel forces it into the mouth, to replace the air that has been drawn from the mouth by the dilatation of the thorax. In *sucking*, the mouth may be compared to an ordinary syringe; the nozzle of which is represented by the lips; the body by the cheeks, palate, &c., and the piston by the tongue. To put this in action, the lips are accurately adjusted around the body from which the liquid has to be extracted. The tongue is likewise applied, contracts, and is carried backwards; so that an approach to a vacuum is formed between its upper surface and the palate. The fluid, no longer compressed equally by the atmosphere, is displaced, and enters the mouth.

As neither mastication nor insalivation is required in the case of liquids, they do not remain long in the mouth, unless their temperature is too elevated to admit of their being passed down into the stomach immediately, or they are of so luscious a character, that their prolonged application to the organ of taste affords pleasure. Their deglutition is effected by the same mechanism as that of solids; and, as they yield readily to the slightest pressure, with less difficulty. Their accumulation in the stomach takes place in much the same manner. They arrive by successive mouthfuls; and, as they collect, the thirst disappears with all its local and general attendants. If, however, the organ be over-distended a disposition to vomiting is induced.

The changes, which liquids undergo in the stomach, are of different kinds. All acquire the temperature of that viscus, and become mixed with the secretions from its internal surface, as well as from that of the supra-diaphragmatic portion of the digestive tube. Some, however, undergo the operation of chymification; others not. To the latter class belong,—water, weak alcoholic drinks, the vegetable acids, &c. Water experiences the admixture already mentioned; becomes turbid, and gradually disappears, without undergoing any transformation. Part passes into the small intestine; the other is directly absorbed. When any strong alcoholic liquor is taken, the effect is different. Its stimulation causes the stomach to contract, and augments the secretion from the mucous membrane; whilst, at the same time, it coagulates all the albuminous and mucous portions; mixes with the watery part of the mucous and salivary fluids, and rapidly disappears by absorption; hence, the speedy supervention of inebriety, or death, after a large quantity of alcohol has been taken into the stomach. The substances, that have been coagulated by the action of the alcohol, are afterwards digested like solid food. We can thus understand the good effects of a small quantity of alcohol, taken after a substance difficult of digestion,—a custom which has existed from high antiquity, and has physiology in its favour. It is, in such cases,—to use the language of the eccentric Kitchener,[1]—a good "*peristaltic persuader.*"

Oil remains longer in the stomach than any other liquid, experiences little change there, but passes into the small intestine, where it forms an emulsion and enters the veins and chyliferous vessels. Milk, as is

[1] Directions for Invigorating and Prolonging Life; or the Invalid's Oracle, &c., Amer. edit., from the 6th London, by T. S. Barrett, New York, 1831.

well known, coagulates in the stomach soon after it is swallowed, after which the clot is digested, and the whey absorbed. Yet the existence of coagula in the stomach is constantly regarded by the unprofessional as a pathological condition! Where the liquid, aqueous or spirituous, holds in suspension the immediate principles of animals or vegetables, as gelatin, albumen, osmazome, sugar, gum, fecula, colouring matter, &c., there is reason to believe that they enter immediately into the veins of the stomach and small intestine. The salts, united with these fluids, are taken up along with them. Red wine, according to M. Magendie,[1] first becomes turbid by admixture with the juices formed in or carried into, the stomach: the albumen of these fluids speedily undergoes coagulation, and becomes flocculent; and, subsequently, its colouring matter—entangled, perhaps, with the mucus and albumen—is deposited on the mucous membrane of the stomach. The aqueous and alcoholic portions soon disappear.

Liquids reach the small intestine in two forms;—in the state of chyme; and in their unaltered condition. In the former case, they proceed like the chyme obtained from solid food. In the latter, they undergo no essential change; being simply united with the fluids poured into the small intestine,—the mucous secretions, bile and pancreatic juice. Their absorption goes on as they proceed, so that very little, if any, attains the large intestine. The mode in which they are expelled is the same as in the case of solids.

6. ERUCTATION, REGURGITATION, AND RUMINATION.

Although the contraction of the œsophagus generally prevents the return of matters from the stomach, occasionally this occurs, giving rise to *eructation*, *regurgitation*, or *vomiting*.

a. *Eructation.*—Eructation or belching is the escape of gas from the stomach. If air exists in the organ, it is necessarily situate near the cardiac orifice. When the aperture relaxes, it passes out, and, unless forced back by the contraction of the œsophagus, speedily reaches the pharynx, causing the edges to vibrate, hence the sound by which it is accompanied.

b. *Regurgitation.*—If, instead of air, liquid or solid food ascends from the stomach into the mouth, the action is called *regurgitation*. Of this we have an instance in the puking of the infant at the breast; and in the adult, when the stomach is surcharged. Occasionally, too, it occurs when the organ is empty,—in the morning, for example;—when it is frequently preceded by eructations, by which the air, contained in the organ, is got rid of. The mode in which it takes place is analogous to that of eructation. The substances, contained in the stomach become accidentally engaged in the cardiac orifice, during the open state of the orifice, and the relaxation of the lower part of the œsophagus, owing to the direct pressure of the stomach on its contents, and the abdominal muscles contracting and compressing that viscus. When they have once passed into the œsophagus, the latter contracts upon them but inversely, or from below to above. In this way they

[1] Precis, &c., ii. 143.

ascend into the pharynx, and ultimately into the mouth. Generally, regurgitation takes place in an involuntary manner; but there are some who are capable of effecting it at will; and can discharge the contents of their stomachs at pleasure. To accomplish this,—a deep inspiration is taken, by which the diaphragm is forcibly depressed upon the stomach; the abdominal muscles are then contracted so as to compress the organ; and this effect is occasionally aided by pressing strongly with the hands on the epigastric region. When these efforts are simultaneous with the relaxation of the lower third of the œsophagus, the alimentary matters pass into the œsophagus. This voluntary regurgitation seems to be what is called *vomiting at pleasure.*

c. *Rumination.*—Some individuals have taken advantage of this power to chew the food over again, and subject it to a second deglutition. The function of *rumination* is peculiar to certain animals; yet man has occasionally possessed it. Peyer,[1] as well as Percy and Laurent,[2] has given numerous examples. The wife of a *frotteur* or rubber of the floors, in the establishment of the then Duke of Orleans,—afterwards King Louis Philippe—could bring up a glassful of water into her mouth immediately after she had swallowed it. Dr. Copland[3] appears to have seen more than one instance of human rumination, and he describes it as an affection rather to be courted than shunned, so far as regards the sensations of the individual. Under usual circumstances, according to him, rumination commences from a quarter of an hour to an hour and a half after a meal. The process is never accompanied with the smallest degree of nausea, pain, or disagreeable sensation. The returned alimentary bolus is attended with no unpleasant flavour; is in no degree acidulous [?]; is agreeable; and masticated with additional pleasure, and greater deliberation than at first. The whole of the food swallowed at a meal is not returned in order to undergo the process; but chiefly the part that has been insufficiently masticated. The more fluid portions are sometimes, however, regurgitated along with the more solid; and when the stomach is distended by a copious meal the fluid contents are frequently passed up to be again swallowed.[4]

d. *Vomiting.*—This inverted action of the stomach, preceded—as it always is—by manifest local and general disturbance, cannot properly be regarded as within the domain of physiology. In the language of Haller, *vomitus totus morbosus est.* It is, however, so nearly allied to the phenomena we have just considered, and has engaged so much of the time of the physiologist, as well as pathologist, that it requires mention here. From regurgitation it differs essentially,—in the sensation that precedes; the retching that accompanies; and the fatigue that generally succeeds it; in short, whilst in regurgitation no indisposition may be felt, in vomiting it is always present to a greater or less extent.

The *sensation of the desire to vomit* is termed *nausea.* It is an in-

[1] Merycologia, &c., Basil, 1685.

[2] Art. Merycisme, in Dict. des Sciences Médicales; Bérard, Cours de Physiologie, 13te livraison, p. 274, Paris, 1849.

[3] Edition of De Lys's translation of Richerand's Physiology.

[4] An interesting case of rumination is cited from the London Lancet, in the Philadelphia Med. Examiner, p. 315, for May, 1845.

describable feeling of general indisposition; sometimes accompanied with one of circumgyration, either in the head or epigastric region; trembling of the lower lip, and copious flow of saliva. Along with these signs, there is manifest diminution of the powers of the vascular and nervous systems; hence the utility of nauseating remedies when these systems are inordinately excited. The causes, which produce nausea, show that it may be either an external or internal sensation. Those, that occasion it directly or externally, are emetics; too great distension of the stomach, or the presence of food that disagrees by its quality; morbid secretions; reflux of bile from the duodenum, &c. All these are so many immediate irritants, which develope the sensation, as external sensations in general are developed. In other cases, the cause acts at a distance. Between the stomach and various organs of the body, such extensive sympathetic relations exist, that if one be long and painfully affected, the stomach sooner or later sympathizes; and nausea, or vomiting, or both are induced. In many instances, indeed, the cause is much more remote than this; the sight of a disgusting object, an offensive smell, or a nauseous taste, will as certainly produce the sensation as any of the more direct agents. To this class of causes belongs the nausea produced by riding in a carriage with the back to the horses, by swinging, and particularly by sailing on the ocean. How the motion, which obviously excites the nausea in these cases, acts, has been the subject of many speculations, especially as regards sea-sickness. Darwin[1] refers it to an association with some affection of the organs of vision, which, in the first instance, produces vertigo; and M. Bourru, in his French translation of the work of Gilchrist, "On the utility of sea voyages in the cure of different diseases,"—ascribes it to irritation of the optic nerves, caused by the impossibility of fixing the eyes on objects soon after embarking. The objections to these views are, that it ought to be prevented by simply covering the eyes, and that the blind ought to be exempt from it, which is not the case. Dr. Wollaston[2] attempted to explain it, by some change in the distribution of the blood;—the descending motion of the vessel causing an accumulation in the brain, as it causes the mercury to rise in the tube of a barometer. But the explanation is too physical. The mercury, in an unyielding tube, is readily influenced by the motions of the vessel; but the blood in the living animal is circumstanced far otherwise. It is under the influence of a vital force, which interferes greatly with the action of purely physical causes. Were it otherwise, we should be liable to alarming accidents, whenever the body is exposed to the slightest concussion.

The generality of pathologists consider, that the first effect is upon the brain, the sensation being produced consecutively through the influence of that organ on the stomach; and it is difficult not to accord with this view; whilst it must be admitted, that the precise mode, in which it is effected, is beyond our cognizance—as in the case, indeed, of every other phenomenon of the nervous system. In nausea, produced by the sight of a disgusting object, we have this catenation of actions somewhat more clearly evidenced. The impression is manifestly,

[1] Zoonomia, iv. 252, 3d edit., Lond., 1801.

[2] Philos. Transact. for 1810.

conveyed to the brain by the optic nerves, and from that organ the sensation must emanate. It is probable, too, that when emetics are injected into the veins, the first effect takes place on the brain, and the stomach is affected secondarily.

When the state of nausea, howsoever induced, continues for any length of time, it is usually followed by vomiting. The rejected matters are generally from the stomach; but if the retching or violent contractile efforts of the muscles concerned be long continued, the contents of the small intestine also form part; hence, we account for the universality of the presence of bile in the rejected matters after an emetic has been taken. Its presence is, therefore, in the generality of cases, no evidence of the person's being what is termed *bilious*. The contents of the small intestine are returned into the stomach by the antiperistaltic action. The longitudinal fibres take their fixed point below, and contract from above downwards; so that the chymous mass is forced towards the upper part of the canal, whilst the circular fibres contract from below to above. In cases of *colica ileus* or *iliac passion*, the inverted action extends through the whole intestinal canal; so that fæcal matters, and even substances injected into the rectum, pass the ileo-cæcal valve, and are discharged by the mouth.

Of old, it was universally maintained, that vomiting is caused by the sudden and convulsive inverted contraction of the stomach; and they, who admitted that the diaphragm and abdominal muscles take part in the action, looked upon them simply as accessories. Francis Bayle,[1] Professor in the University of Toulouse, in 1681, appears to have been the first who suggested, that the stomach is nearly passive in the act; and that vomiting is caused almost exclusively by the pressure exerted upon that organ by the diaphragm and abdominal muscles. His reason for the belief was founded on the fact, that having introduced his finger into the abdomen of a living animal whilst it was vomiting he could not perceive any contraction of the stomach. In 1686, M. Chirac repeated the experiment with similar results; after which, the views of Bayle were embraced by many of the most eminent physiologists and pathologists,—Sénac, Van Swieten, and Schwartz,[2] and, at a later period, by the celebrated John Hunter,[3] who maintained, that the contraction of the muscular fibres of the stomach is not essential to the act. Many distinguished physiologists ranged themselves on the opposite side. M. Littre maintained, that the stomach is provided with considerable muscular bands, capable of powerful contraction; and that vomiting, as in the case of ruminant animals, is often caused without the participation of the abdominal muscles. We have seen, however, that the rumination of animals more resembles regurgitation. M. Lieutaud[4] argued, that, according to Bayle's theory, vomiting ought to be a voluntary phenomenon; that the stomach is too deeply seated to be compressed, so as to empty it of its contents, by the neighbouring muscles;

[1] Problemata Medico-physica et Medica, Hagæ Comitis, 1678.
[2] Haller, Elementa Physiol., lib. xix. § 4, Bern., 1764.
[3] Observations on certain parts of the Animal Economy, with Notes by Prof. Owen, Amer. edit., p. 121, Philad., 1840.
[4] Mémoir. de l'Acad. pour 1752, p. 223.

and he details the singular case of a female, who, whilst labouring under an affection, for which emetics seemed to be required, resisted the action of the most powerful substances of that nature. After her death, M. Lieutaud, feeling desirous to detect the cause of this resistance, had the body opened in his presence: the stomach was found enormously distended, but its structure unaffected. He, consequently, inferred, that the stomach had become paralysed from over-distension, and that the effect produced was similar to that, so often met with in the bladder, when it has been long and largely distended. This case seemed to prove to him, that the stomach is most concerned in the act of vomiting, as the abdominal muscles and diaphragm appeared healthy, and no obstacle existed to their contraction. It is singular, however, that emetics should not have excited the contraction of the diaphragm and abdominal muscles; especially as there is reason for believing, that many of them at least, under ordinary circumstances, are taken into the bloodvessels, and affect the brain first, and through its agency the muscles concerned in the act of vomiting. The case seems to have been one of unusual resistance to the ordinary effects of nauseating substances, and cannot be looked upon as either favourable or unfavourable to the views of Bayle. We find, that vomiting does not follow the exhibition of the largest doses of the most powerful emetics, if the energy of the nervous system be suspended by the inordinate use of narcotics, or by violent injuries of the head. M. Lieutaud farther remarks, that according to Bayle's theory vomiting occurs at the time of inspiration; but this cannot be, as the lower part of the œsophagus is then contracted, and if the vomited matters could reach the pharynx, they would pass into the larynx.

Dr. Marshall Hall[1] has attempted, and successfully, to show, that the larynx is closed during vomiting; and has concluded, that the act is a modification of expiration,—or that the muscles of expiration, by a sudden and violent contraction, press upon the contents of the stomach, and project them through the œsophagus. Perhaps—as Dr. Hall has remarked—no act affords a better illustration of the action of the excito-motory or reflex system of nerves than this. If the upper part of the throat be tickled with a feather, vomiting results; but if the feather be passed too far down, deglutition is induced and not vomiting. The excitor nerves, in the former case, are the glosso-pharyngeal, and perhaps the fifth pair. When vomiting is caused by an emetic, the pneumogastric is the excitor. When the impression is first made on the brain, the stimulus must be conveyed by the medulla oblongata and medulla spinalis to the muscles concerned.

Haller[2] maintained the ancient doctrine, that the stomach, alone, is competent to the operation. His views were chiefly founded on his theory of irritability, which compelled him to admit contraction wherever there are muscular fibres; and on certain experiments of Wepfer,[3] who asserted, that when he produced vomiting by mineral substances, he observed the stomach contract. The *Académie des Sciences* of Paris,

[1] Journal of Science and Arts, xv. 388.

[2] Loc. citat.

[3] Cicutæ Aquaticæ Historia, &c., Basil, 1679.

unsatisfied with the results of previous observations, appointed M. Duverney[1] to examine into the question, experimentally and otherwise; who,—although he did not adopt the whole theory of Chirac—confirmed the accuracy of the facts on which it rested. He demonstrated, that the stomach is but little concerned in the act; and that it is chiefly dependent upon the contraction of the diaphragm and abdominal muscles, which enclose the stomach as in a press, so that its contents are compelled to return by the œsophagus. On the other hand, in 1771, M. Portal,[2] in his lectures at the College of France, endeavoured to show, that the stomach is the great agent. He administered to two dogs arsenic and nux vomica, which produced vomiting. The abdomen was immediately opened; and, according to Portal, the contractile movements of the stomach could be both seen and felt; and it was noticed, that instead of the vomiting being dependent upon the pressure of the diaphragm on the stomach, it occurred at the time of expiration; and was arrested during inspiration, because the depressed diaphragm then closes the inferior extremity of the œsophagus with such strength, that the contents cannot be forced into the œsophagus when we press upon the organ with both hands. The views of Portal were confirmed by the experiments of Dr. Haighton.[3] He opened several animals during the efforts of vomiting; and states that he distinctly saw the contractions of the stomach.

In more recent times, the physiological world has been again agitated with this question. In 1813, M. Magendie[4] presented to the French Institute the results of a series of experiments on dogs and cats,—animals, that vomit with facility. Six grains of tartrate of antimony and potassa were given to a dog, and, when he became affected with nausea, the linea alba was divided, and the finger introduced into the abdomen to detect the state of the stomach. No contraction was felt; the organ appeared simply pressed upon by the liver and intestines crowded upon it by the contracted diaphragm and abdominal muscles. Nor was any contraction of the stomach perceptible to the eye; on the contrary, it appeared full of air, and three times its usual size. The air manifestly came from the œsophagus, as a ligature, applied round the cardia, completely shut it off. From this experiment, M. Magendie inferred, that the stomach is passive in vomiting. A solution of four grains of tartrate of antimony and potassa in two ounces of water was injected into the veins of a dog; and, as soon as nausea took place, an incision was made into the abdomen, and the stomach drawn out of the cavity. Although the retching continued, the viscus remained immovable; and the efforts were vain. If, on the other hand, the anterior and posterior surfaces of the stomach were pressed upon by the hands, vomiting occurred, even when no tartrate was administered,—the pressure provoking the contraction of the diaphragm and abdominal muscles, and thus exhibiting the close sympathetic connexion, existing between those acts. A slight pull at the œsophagus was attended with a similar

[1] Mémoir de l'Académ. pour 1700, Hist., p. 27.
[2] Cours d'Anatomie Médicale, Paris, 1804.
[3] Memoirs of the Lond. Med. Society, vol. ii.
[4] Mémoire sur le Vomissement, Paris, 1813; and Précis Elémentaire, edit. cit., ii. 152.

result. In another dog, the abdomen was opened; the vessels of the stomach tied; and the viscus extirpated. A solution of two grains of tartrate of antimony and potassa in an ounce and a half of water was then injected into the veins of the animal, when nausea and fruitless efforts to vomit supervened. The injection was repeated six times: and always with the same results.—In another dog, the stomach was extirpated, and a hog's bladder fitted to the œsophagus in its stead, containing a pint of water, which distended but did not fill it. The whole was then put into the abdomen; the parietes of which were closed by suture. A solution of tartrate of antimony and potassa was now injected into the jugular vein: nausea—and, afterwards, vomiting—supervened, and the fluid was forced from the bladder.—In another dog, the phrenic nerves were divided; by which three-fourths of the diaphragm were paralysed; the dorsal being the only nerves of motion remaining untouched. When tartrate of antimony and potassa was injected into the veins of this animal, but slight vomiting occurred; and this ceased, when the abdomen was opened, and the stomach forcibly pressed upon.—In another dog, the abdominal muscles were detached from the sides and linea alba;—the only part of the parietes remaining being the peritoneum. A solution of tartrate of antimony and potassa was now injected into the veins: nausea and vomiting supervened; and, through the peritoneum, the stomach was observed immovable; whilst the diaphragm pressed down the viscera so strongly against the peritoneum, that it gave way, and the linea alba alone resisted.—In a final experiment, he combined the two last. He cut the phrenic nerves to paralyse the diaphragm; and removed the abdominal muscles. Vomiting was no longer excited.

From these different results, M. Magendie decided, that vomiting takes place independently of the stomach; and, on the other hand, that it cannot occur without the agency of the diaphragm and abdominal muscles; and he concluded, that the stomach is almost passive in the act;—that the diaphragm and abdominal muscles, especially the first, are the principal agents;—that air is constantly swallowed at the time of vomiting, to give the stomach the bulk which is necessary, in order that it may be compressed by those muscles; and lastly, that the diaphragm and abdominal muscles are largely concerned in vomiting, as is indicated by their evident and powerful contractions, and by the fatigue felt in them afterwards. In corroboration of his view, M. Magendie refers to cases of scirrhous pylorus, in which there is constant vomiting, although a part of the tissue of the stomach has become of cartilaginous hardness, and, consequently, incapable of contraction.

Clear as the results obtained by this practiced experimenter seem to be, they have been controverted; and attempted to be overthrown by similar experiments. Soon after the appearance of his memoir, M. Maingault[1] laid before the Society of the *Faculté de Médecine* of Paris, a series of experiments, from which he deduced very different results. In all, vomiting was produced without the aid of the diaphragm and abdominal muscles. The vomiting was excited, by pinching a por-

[1] Mémoire sur le Vomissement, Paris, 1813.

tion of intestine, which acts more speedily than the injection of substances into the veins. The abdomen of a dog was opened, and a ligature passed round a portion of intestine, which was returned into the abdomen, and the wound closed by suture: vomiting took place. All the abdominal muscles were next extirpated,—the skin, alone, forming the parietes of the cavity. This was brought together, and the vomiting continued. On another dog, three-quarters of the diaphragm were paralysed by the section of the phrenic nerves. The abdomen was now opened, and a ligature placed round a portion of intestine. Vomiting occurred. Lastly;—these two experiments were united into one. The abdominal muscles were cut crucially, and removed; the phrenic nerves divided; and the diaphragm was cut away from its fleshy portion towards its tendinous centre; leaving only a portion as broad as the finger under the sternum. The integuments were not brought together; yet vomiting continued.

As these results were obtained on numerous repetitions of the experiment, M. Maingault conceived himself justified in deducing inferences opposite to those of M. Magendie, namely,—that the contraction of the diaphragm and abdominal muscles is only accessory to the act of vomiting; that the action of the stomach is its principal cause;—that the latter is not a convulsive contraction, which strikes the eye, but a slow, antiperistaltic action; and that the only convulsive movement is the contraction of the œsophagus, which drags the stomach upwards. He adduces, moreover, various considerations in favour of his deductions. If the stomach, he asks, be passive, why does it possess nerves, vessels, and muscular fibres? Why is vomiting more energetic, when the stomach is pinched nearer to its pyloric orifice? Why are the rugæ of the mucous membrane of the stomach, during vomiting, directed in a divergent manner from the cardiac and pyloric orifices towards the middle portion of the organ? If the diaphragm does all, why do we not vomit whenever that muscle contracts forcibly? Why does not the diaphragm produce the discharge of urine in paralysis of the bladder? Why is vomiting not a voluntary phenomenon? And, lastly, how is it that it occurs in birds, which have no diaphragm?

The minds of physiologists were of course distracted by these conflicting results. M. Richerand[1] embraced the views of M. Magendie; and affirmed, that he had never observed contraction of the stomach; and that it seemed to him the least contractile of any part of the intestinal canal. With regard to the experiments of M. Maingault, he considered, that the stomach had not been wholly separated from the surrounding muscles; that the action of the pillars of the diaphragm, and the spasmodic constriction of the hypochondres are sufficient to compress the viscus; that nothing is more difficult to effect than the section of the phrenic nerves below their last root; and, moreover, such section does not entirely paralyse the diaphragm, as the muscle still receives twigs from the intercostal nerves and great sympathetic; that the cardia, being more expanded than the pylorus, the passage of substances through it is rendered easy; and that it is incorrect to say, that the

[1] Nouveaux Elémens de Physiologie, 7ème edit., Paris, 1817.

cardiac orifice, during inspiration, is closed between the pillars of the diaphragm. Again, to object that, according to the theory of M. Magendie, vomiting ought to be a voluntary phenomenon, is a feeble argument; for it is admitted, that the muscles, which, at the time, compress the stomach, act convulsively. If the diaphragm, in paralysis of the bladder, cannot effect the excretion of the urine, it is because that reservoir is not favourably situate as regards the muscle; and, lastly, the arguments deduced from birds, that they are capable of vomiting, although they have no diaphragm, is equally insufficient, for it is not absolutely necessary that it should be a diaphragm, but any muscle that can compress the stomach.

When the Memoir of M. Maingault was presented to the society of the *Faculté de Médecine*, M. Legallois and Professor Béclard were named reporters. The experiments were repeated before them by M. Maingault; but, instead of appearing contradictory to those of Magendie, these gentlemen declared, that they were not sufficiently multiplied, nor sufficiently various, to lead to any positive conclusion. MM. Legallois and Béclard subsequently repeated and varied them; and instituted others, from which they deduced corollaries, entirely conformable to those of M. Magendie;[1] and lastly, M. Bégin[2] boldly affirms, "without fear of being contradicted by facts, that there is no direct or authentic experiment, that demonstrates the activity of the stomach during vomiting:"—and he adds, "I have repeated the greater part of the experiments of Magendie; he has performed all in presence of a great number of spectators, of whom I was one; and I can say, with the commissioners of the *Académie des Sciences*, that I have seen, examined, touched, and my conviction is full and entire." Still, many eminent physiologists have adhered to the idea, that the stomach is the main agent in vomiting; and among these was M. Broussais.[3] He manifestly, however, confounded the phenomena of regurgitation with those of vomiting; which, we have endeavoured to show, are distinct.

A case of wound of the left hypochondrium with escape of the stomach was described to the *Académie Royale de Médecine*, by M. Lépine, and reported upon by MM. Lagneau, Gimelle, and Bérard,[4] which confirms the views adopted by M. Magendie. During the whole of the period, that the stomach remained out of the abdominal cavity, there was no apparent contraction of the muscular fibres of the organ, and none of its contents were expelled, although the patient made violent efforts to vomit. As soon, however, as the stomach had been returned into the abdomen, the efforts were followed by the expulsion of its contents. M. Lépine confirms the observations of Magendie in another point. After each act of vomiting, the patient appeared to swallow air. "I observed him," says M. Lépine, "execute repeated

[1] Bulletin de la Faculté et de la Société de Méd., 1813, No. x., and Œuvres de Legallois, Paris, 1824.
[2] Traité de Thérapeutique, Paris, 1825.
[3] Traité de Physiologie, etc., Drs. Bell and La Roche's translation, p. 345, Philad., 1832.
[4] Bulletin de l'Académie Royale de Médecine, 1844. See the cases cited in Philad. Med. Examiner, April 20, 1844, p. 92; also a case of Wound of Abdomen, in Amer. Journ. of the Med. Sciences, Oct., 1846, p. 379.

acts of deglutition, each of which was accompanied by a noise, that seemed to be owing to the passing back of air."

On the whole, we are, perhaps, justified in concluding, that the ancient doctrine regarding vomiting is full of error, and ought to be discarded; that the inverted action of the stomach, although not energetic, is necessary,—that the pressure, exerted on the parietes of the stomach by the diaphragm and abdominal muscles, is a powerful cause, —and that the more or less complete paralysis of the diaphragm, or destruction of the abdominal muscles, renders vomiting more feeble and more slow in manifesting itself. The deep inspiration preceding the act of vomiting, is terminated by the closure of the glottis: after this the diaphragm cannot move without expanding or compressing the air in the lungs. It, consequently, presents a resisting surface, against which the stomach may be pressed by the contracting abdominal muscles. The order of the phenomena seems to be as follows. The brain is affected directly or indirectly by the cause exciting vomiting;—through the brain and medulla, the glottis is closed, and the diaphragm and abdominal muscles are thrown into appropriate contraction, and press upon the stomach; this organ probably contracts from the pylorus towards the cardia; and, by the combination of efforts, the contents are propelled into the œsophagus, and out of the mouth. These efforts are repeated several times in succession, and then cease, —to reappear at times. Whilst the rejected matters pass through the pharynx and mouth, the glottis closes; the velum palati rises and becomes horizontal as in deglutition; but owing to the convulsive action of the parts, these apertures are less accurately closed, and more or less of the vomited matter passes into the larynx or nasal fossæ. On account of the suspension of respiration impeding the return of blood from the upper parts of the body, and partly owing to the force with which the blood is sent through the arteries, the face is flushed, or livid, the perspiration flows in abundance, and the secretion of tears is largely augmented.

CHAPTER II.

ABSORPTION.

In the consideration of the preceding functions, we have seen the alimentary matter subjected to various actions and alterations; and at length, in the small intestine, possessed of the necessary physical constitution for the chyle to be separated from it. Into the mode in which this separation,—which we shall find is not simply a secerning action, but one of vital elaboration,—is effected, we have now to inquire. It constitutes the function of *absorption*, and its object is to convey the nutritive fluid, formed from the food, into the current of the circulation. Absorption is not, however, confined to the formation of this fluid. Liquids can pass into the blood directly through the coats of the containing vessel, without having been subjected to any elaboration; and the different constituents of the organs are constantly sub-

jected to the absorbing action of cells, by which their decomposition is effected, and their elements conveyed into the blood; whilst antagonizing cells elaborate from the blood, and deposit fresh particles in the place of those that have been removed. These various substances,—bone, muscle, hair, nail, as the case may be,—are never found, in their compound state, in the blood; and the inference, consequently, is that at the very radicles of the absorbents and exhalants, the substance on which absorption or exhalation has to be effected, is reduced to its constituents, and this by an action, to which we know nothing similar in physics or chemistry: hence, it has been inferred, that the operation is one of the acts of vitality.

All the various absorptions may be classed under two heads:—the *external* and the *internal;* the former including those that take place on extraneous matters from the surface of the body or its prolongation—the mucous membranes; and the latter, those that are effected internally, on matters proceeding from the body itself, by the removal of parts already deposited. By some physiologists, the action of the air in respiration has been referred to the former of these; and the whole function of absorption has been defined;—the aggregate of actions, by which nutritive substances—external and internal—are converted into fluids, which serve as the basis of arterial blood. The function of respiration will be investigated separately. Our attention will, at present, be directed to the other varieties; and, first of all to that which occurs in the digestive tube.

I. DIGESTIVE ABSORPTION.

The absorption, effected in the organs of digestion, is of two kinds; according as it concerns liquids of a certain degree of tenuity, or solids. The former, it has been remarked, are subjected to no digestive action, but disappear chiefly from the stomach, and in part from the small intestine. The latter undergo conversion, before they are fitted to be taken up from the intestinal canal.

a. *Absorption of Chyle or Chylosis.*

1. ANATOMY OF THE CHYLIFEROUS APPARATUS.

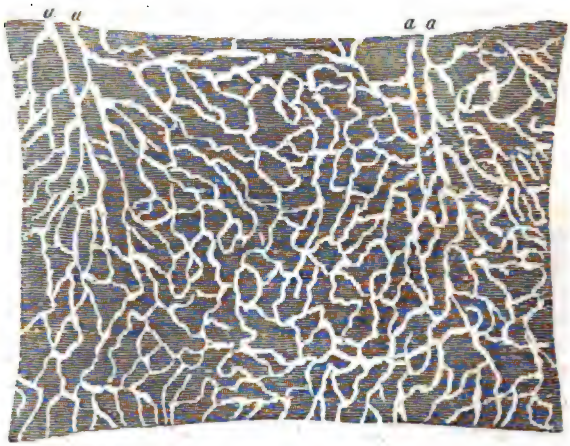
In the lower animals, absorption is effected over the whole surface of the body, both as regards the materials necessary for nutrition and the supply of air. No distinct organs for the performance of these functions are perceptible. In the upper classes of animals, however, we find an apparatus, manifestly intended for the absorption of chyle, and constituting a vascular communication between the small intestine and left subclavian. Along this channel, the chyle passes, to be emptied into that venous trunk.

The *chyliferous apparatus* consists of chyliferous vessels, mesenteric glands, and thoracic duct. The *chyliferous vessels* or *lacteals*, arise from the inner surface of the small intestine;—in the villi, which are at the surface of, and between, the valvulæ conniventes. Prof. E. H. Weber[1] has, however, seen them distributed in the interspaces between the

[1] Müller's Archiv., u. s. w., s. 400, Berlin, 1847.

villi; the lacteals and bloodvessels forming a close net-work; but he could not detect them in the parietes of the follicles of Lieberkühn. Their origin is almost imperceptible; and, accordingly, the nature of their arrangement has given occasion to much diversity of sentiment amongst anatomists. Lieberkühn[1] affirms, that, by the microscope, it may be shown that each villus terminates in an *ampullula* or oval vesicle, which has its apex perforated by lateral orifices, through which the chyle enters. The doctrine of open mouths of lacteals and lymphatics was embraced by Hewson,[2] Sheldon,[3] Cruikshank,[4] Hedwig,[5] and Bleuland,[6] and by some of the anatomists and physiologists of the present day;[7] but, on the other hand, it has been contested by Mascagni,[8] and others; whilst Rudolphi,[9] Meckel,[10] and numerous others[11] believed, that the lacteals have not free orifices; but that in the villi, in which absorption is effected, a spongy or sort of gelatinous tissue exists, which accomplishes absorption, and, being continuous with the mouths of chyliferous vessels, conveys the product of absorption into them. Bichat conceived them to commence by a kind of sucker or absorbing mouth, the action of which he compared to that of the puncta lachrymalia or of a leech or cupping-glass; and lastly,—from the observation, often made, that different coloured fluids, with which the lymphatics have been injected, have never spread themselves, either into the areolar tissue, or the parenchyma of the viscera,—M. Mojon,[12] of Genoa, affirmed, that lymphatics have no patulous orifice, and that they take

Fig. 249.

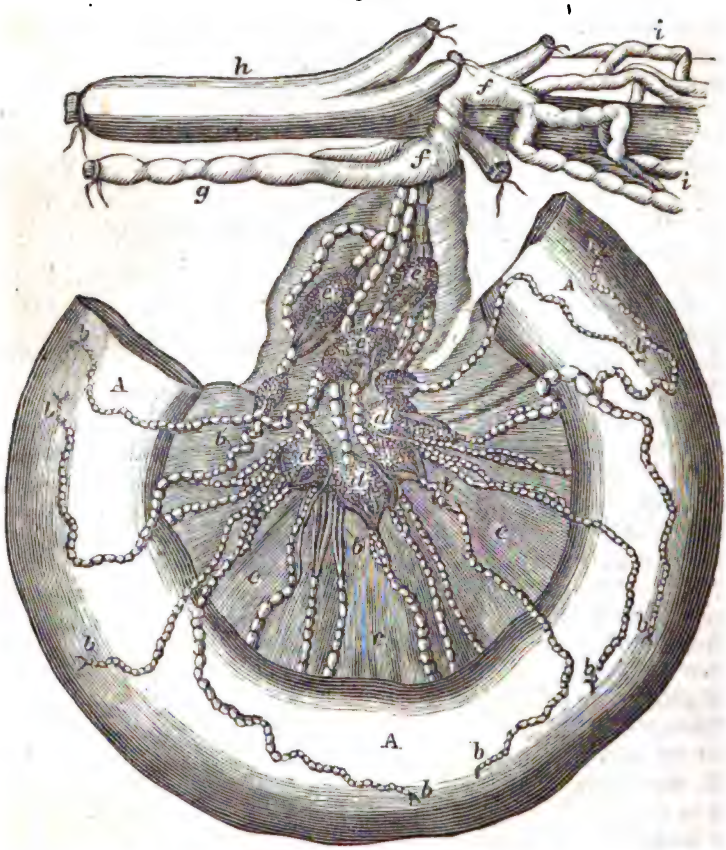


Chyliferous Vessels.

[1] Dissert. de Fabric. Villor. Intest. passim. Lugd., Bat., 1745.
[2] Experimental Inquiries; edited by Falconer, Lond., 1774, 1777, and 1780, or Hewson's Works, Sydenham Society's edit., p. 181, Lond., 1846.
[3] The History of the Absorbent System, &c., p. 1, Lond., 1784.
[4] Anatomy of the Absorbing Vessels, 2d edit., Lond., 1790.
[5] Disquisit. Ampull. Lieberkühnii, Lips., 1797.
[6] Exper. Anatom., 1784; and Descript. Vasculor. in Intestinor Tenuium Tunicis, Ultraj., 1797.
[7] See Henle, Allgemeine Anatomie, u. s. w. s. 569, Leipz., 1841.
[8] Vasorum Lymphaticorum Corporis Humani Historia, &c., Senis, 1787; and Prodromo d'un Opera sul Sistémo de Vase Linfatice, Siena, 1784.
[9] Anatomisch. Physiologisch. Abhandlung., Berlin, 1802.
[10] Handbuch, u. s. w. translated by Jourdan and Breschet, p. 179, Paris, 1805.
[11] F. Arnold, Lehrbuch der Physiologie des Menschen, Zurich, 1836–7; noticed in Brit. and For. Med. Rev., Oct., 1839, p. 479.
[12] Journal de la Société des Sciences Physiques, &c. Nov., 1833.

their origin from a cellular filament, which progressively becomes a villosity, an areolar spongiole, a capillary, and, at length, a lymphatic

Fig. 250.



Chyliferous Apparatus.

A, A. A portion of the jejunum. *b, b, b, b.* Superficial lacteals. *c, c, c.* Mesentery. *d, d, d.* First row of mesenteric glands. *e, e, e.* Second row. *f, f.* Receptaculum chyli. *g.* Thoracic duct. *h.* Aorta. *i, i.* Lymphatics.

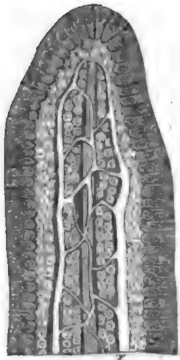
trunk;—the absorbent action of these vessels being a kind of imbibition. Lastly, Professor Müller[1] affirms, that he has never perceived any opening at the extremity of the villi: in his earlier examinations, he was unable to see appearances of foramina on any part of their surface, but he has observed, in portions of the intestines of the sheep and the ox, which had been exposed for some time to the action of water, that over the whole surface of the villi indistinct depressions were scattered, which might be regarded as oblique openings. He adds, however, that he makes this observation with great hesitation and distrust.

[1] Handbuch der Physiologie, u. s. w., and Baly's translation, p. 269, Lond., 1838.

All these are mere speculations, too often entirely gratuitous; and the view, that they never open by free orifices on the surface of the intestine, as was formerly imagined, is entirely in accordance with the results of modern histological inquiries.

The marginal illustration, Fig. 252, from Krause exhibits the appearance presented by the incipient chyliferous vessels in the villi of the jejunum of a young man, who had been hanged soon after taking a full meal of farinaceous food. The chyliferous vessel issuing from each villus appeared to arise by several small branches, in some of which free extremities could be traced, whilst others anastomosed with each other. The arrangement of the different anatomical constituents is well seen in Fig. 251, which represents an injected intestinal villus of a cat, which was killed during digestion. When they become perceptible to the eye, they are observed as in Fig. 249, communicating frequently with each other; and forming a minute network, first between the muscular and mucous membranes, and afterwards between the muscular and peritoneal, until they terminate in larger trunks, *a*, *a*, *a*, *a*. When they attain the point at which the peritoneal coat quits the intestine, they also leave it; creep for an inch or two in the substance of the mesentery; and enter a first row of mesenteric glands. From these they issue, of a greater size and in less number; proceed still farther along the mesentery, and reach a second row, into which they enter. From these, again, they issue, larger and less numerous; anastomosing with each other; and proceeding towards the lumbar portion of the spine, where they terminate in a common reservoir,—the *reservoir* of Pecquet, *receptaculum* seu *cisterna chyli*, (Figs. 250 and 253)—which is the commencement of the thoracic duct. This reservoir is situate about the third lumbar vertebra; behind the right pillar of the diaphragm, and the right renal vessels. The chyliferous vessels generally follow the course of the arteries; but sometimes proceed in the spaces between them. They exist in the lower part of the duodenum, throughout the whole of the jejunum, and in the upper part of the ileum. M. Voisin[1] affirms, that all, or at least the major part, of them pass through the substance of the liver, before they empty their contents into the thoracic duct. After proceeding a certain distance, they anastomose, he says, with each other, enlarge in size, and are collected together so as to form a kind of plexus below the

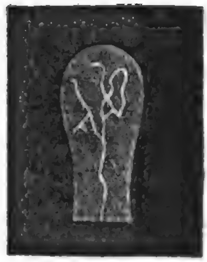
Fig. 251.



Section of Intestinal Villus. (Gerlach.)

a. Artery. *b.* Vein. *c.* Lymphatic. — Magnified 250 diameters.

Fig. 252.



Intestinal Villus with the commencement of a Lacteal. (Krause.)

[1] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.

lobe of Spigelius, towards which they converge. From this point, they penetrate the substance of the liver, through which they ramify with great minuteness, and finally empty themselves into the receptaculum chyli. To prove, that the chyliferous vessels do pass through the liver, he put a ligature around the duct below the diaphragm, in a dog which had eaten largely, and when digestion was in full activity. The chyliferous vessels were observed to swell, and their whitish colour was distinctly perceived. They could be traced, without much difficulty, from the interior of the intestinal canal, through the mesenteric glands, as far as their entrance into the liver.

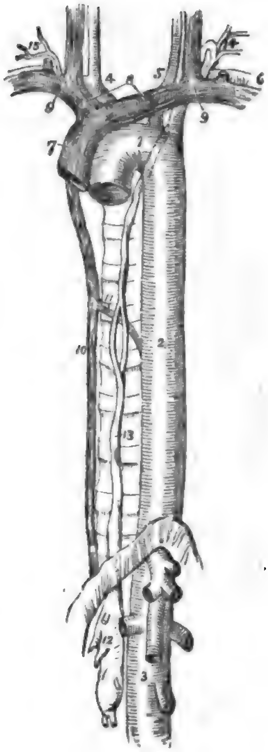
The chyliferous vessels are composed of two coats; the outer of a fibrous and firm character; the inner very thin, epithelial, and generally considered to form, by its duplicatures, *valves*. These are of a semilunar form, arranged in pairs, and with the convex side towards the intestine. Their arrangement has appeared to be well adapted for permitting the chyle to flow from the intestine to the thoracic duct, and for preventing its retrograde course; but M. Magendie[1] affirms, that their existence is by no means constant. These reputed valves are considered by M. Mojon[2] to be true sphincters. By placing the lymphatic vessels on a glass plate, and opening them through their entire length, he observed by the microscope, that they are formed of circular fibres, which, by diminishing the size of the vessel at different points, give rise to the nodosities observed externally. If the ends of a varicose lymphatic be drawn in a contrary direction, these nodosities disappear, as well as the supposititious valves. Mojon observed, moreover, that the fibrous membrane of the lymphatics has longitudinal, as well as oblique, filaments passing from one narrow portion to another. The longitudinal fibres have their two extremities attached to the transverse fibres, which, according to him, constitute the sphincters or contractors of the lymphatics. He explains the difficulty often experienced in attempting to inject the lymphatic vessels in a direction contrary to the course of the lymph, by the circumstance, that the little pouches formed by the sphincters, and the relaxation or distension of their parietes on filling them with injected matter, diminish the calibre of the tube, and can even close it entirely. The smallest lacteals appear to be destitute of valves; but valves are perceptible in those of less than one-third of a line in diameter, and they have the same structure as those of the veins. The minute lacteals in the villi are said to consist of a single membrane with elongated cell-nuclei, corresponding to the longitudinal fibrous membrane of the veins, but not lined by epithelium. Some anatomists describe an external coat, formed of condensed areolar tissue, which unites the chyliferous vessels to the neighbouring parts.

The *mesenteric glands* or *ganglions* are small, irregularly lenticular organs; varying in size from the sixth of an inch to an inch; nearly one hundred in number, and situate between the two laminæ of the mesentery. In them, the lymphatic vessels of the abdomen termi-

[1] Précis Elémentaire, 2de edit., ii. 177, Paris, 1825.
[2] Op. citat. and Amer. Journal, &c., for Aug. 1834, p. 465.

nate; and the chyliferous vessels traverse them in their course from the intestine to the thoracic duct. Their substance is of a pale rosy colour; and their consistence moderate. By pressure, a transparent and inodorous fluid can be forced from them; which has never been examined chemically. Anatomists differ with regard to their structure. According to some, they consist of a pellet of chyliferous vessels, folded a thousand times upon each other; subdividing and anastomosing almost *ad infinitum;* united by areolar tissue, and receiving a number of bloodvessels. In the opinion of others, again, cells exist in their interior, into which the *afferent* chyliferous vessels open; and whence the *efferent* set out. These are filled with a milky fluid, carried thither by the lacteals or exhaled by the bloodvessels. Notwithstanding the labours of Nuck,[1] Hewson, Abernethy, Mascagni, Cruikshank, Haller,[2] Béclard,[3] and other distinguished anatomists, the texture of these, as well as of the lymphatic glands or ganglions in general, is not demonstrated. The chyliferous and sanguiferous vessels become extremely minute in their substance; and the communication between the afferent and efferent vessels is very easy; as mercurial injections pass readily from the one to the other. Accord-

Fig. 253.



Thoracic Duct.

1. Arch of aorta. 2. Thoracic aorta. 3. Abdominal aorta; showing its principal branches divided near their origin. 4. Arteria innominata, divided into right carotid and right subclavian arteries. 5. Left carotid. 6. Left subclavian. 7. Superior cava, formed by the union of 8, the two venæ innominatæ; and these by the junction 9 of internal jugular and subclavian vein at each side. 10. Greater vena azygos. 11. Termination of the lesser in greater vena azygos. 12. Receptaculum chyli; several lymphatic trunks are seen opening into it. 13. Thoracic duct, dividing opposite middle of dorsal vertebræ into two branches which soon reunite; course of duct behind arch of aorta and left subclavian artery is shown by a dotted line. 14. The duct making its turn at root of the neck and receiving several lymphatic trunks previously to terminating in posterior aspect of junction of internal jugular and subclavian vein. 15. Termination of trunk of ductus lymphaticus dexter.

ing to Mr. Goodsir, the absorbent vessels within the chyliferous and lymphatic glands lay aside all but their internal coat; and the epithelium, instead of forming a thin lining of flat transparent scales, as in the extra-glandular lymphatics, acquires an opaque granular aspect, and is converted into a thick irregular layer of spherical nucleated corpuscles, measuring on an average $\frac{1}{5000}$th part of an inch in diameter, so as to suggest the idea of lymph or chyle corpuscles generated on the internal membrane after the ordinary manner of epithelium cells, and about to be thrown off into the vessel. This layer, according to Mr. Goodsir, is thickest in those lymphatics that are situated towards

[1] Adenologia, Lugd. Bat., 1696.
[2] Element. Physiol., lib. ii. § 3, Lausan., 1757.
[3] Addit. à Bichat, p. 128, Paris, 1821.

Fig. 254.

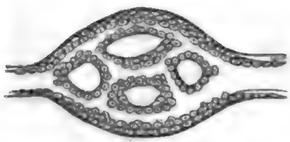


Diagram of a lymphatic gland, showing the intra-glandular network, and the transition from the scale-like epithelia of the extra-glandular lymphatics, to the nucleated cells of the intra-glandular.

Fig. 255.

Portion of the intra-glandular lymphatic, showing along the lower edge the thickness of the germinal membrane, and upon it, the thick layer of glandular epithelial cells.

the centre of the gland, becomes gradually thinner towards the afferent and efferent vessels, and passes continually into the ordinary epithelium.

The *thoracic duct*, *g*, Fig. 250, and 13, Fig. 253, is formed by the junction of the chyliferous trunks with the lymphatic trunks from the lower extremities. The *receptaculum chyli*, already described, forms its commencement. After passing from under the diaphragm, the duct proceeds, in company with the aorta, along the right side of the spine, until it reaches the fifth dorsal vertebra; where it crosses over to the left side behind the œsophagus. It then ascends behind the left carotid artery; runs up to the interstice between the first and second vertebræ of the chest; where, after receiving the lymphatics, which come from the left arm and left side of the head and neck, it suddenly turns downwards, and terminates at the angle formed by the meeting of the subclavian and internal jugular veins of the left side.

To observe the chyliferous apparatus to the greatest advantage, it should be examined in an individual recently executed, or killed suddenly two or three hours after having eaten; or in an animal, destroyed for the purpose of experiment, under similar circumstances. The lacteals are then filled with chyle, and may be readily recognised, especially if the thoracic duct has been previously tied. These vessels were unknown to the ancients. The honour of their discovery is due to Gaspard Aselli,[1] of Cremona, who, in 1622, at the solicitation of some friends, undertook the dissection of a living dog, which had just eaten, in order to demonstrate the recurrent nerves. On opening the abdomen, he perceived a multitude of white, very delicate filaments crossing the mesentery in all directions. At first, he took them to be nerves; but having accidentally cut one, he saw a quantity of a white liquor exude, analogous to cream. Aselli also noticed the valves, but he fell into an important error regarding the destination of the lacteals; believing them to collect in the pancreas, and from thence proceed to the liver. In 1628, the human lacteals were discovered. Gassendi[2] had no sooner heard of the discovery of Aselli, than he spoke of it to his friend Nicholas-Claude-Fabrice de Peiresc, senator of Aix; who seems to have been a most zealous propagator of scientific knowledge. He immedi-

[1] De Lactibus seu Lacteis Venis, &c., Mediol., 1627; also, in Collect. Oper. Spigelii, edit. Van der Linden; and in Manget. Theatr. Anatom.

[2] Vita Peirescii, in Op. omnia, v. 300.

ately bought several copies of the work of Aselli, which had only appeared the year previously; and distributed them amongst his professional friends. Many experiments were made upon animals, but the great desire of De Peiresc was, that the lacteals should be found in the human body. Through his interest, a malefactor, condemned to death, was given up, a short time before his execution, to the anatomists of Aix; who made him eat copiously; and, an hour and a half after execution, opened the body, in which, to the great satisfaction of De Peiresc, the vessels of Aselli were perceived in the clearest manner. Afterwards, in 1634, John Wesling[1] gave the first graphic representation of them as they exist in the human body; and subsequently pointed out more clearly than his predecessors the thoracic duct and lymphatics. Prior to the discovery of the chyliferous and lymphatic vessels, the veins, which arise in immense numbers from the intestines, and, by their union with other veins, form the vena porta, were esteemed the agents of absorption; and, even at the present day, they are considered, by some physiologists, to participate with the chyliferous vessels in the function;—with what propriety we shall inquire hereafter.

2. CHYLE.

The chyle, as it circulates in the chyliferous vessels, has only been submitted to examination in comparatively recent times. It varies in different parts of its course. The best mode of obtaining it is to feed an animal; and, when digestion is in full progress, to strangle it, or divide the spinal marrow beneath the occiput. The thorax must then be opened through its whole length, and a ligature be passed round the aorta, œsophagus, and thoracic duct, as near the neck as possible. If the ribs of the left side be now turned back or broken, the thoracic duct is observed lying against the œsophagus. By detaching the upper part, and cutting into it, the chyle flows out. A small quantity only is thus obtained; but, if the intestinal canal and chyliferous vessels be repeatedly pressed upon, the flow may be sometimes kept up for a quarter of an hour. It is obviously impossible, in this way, to obtain the chyle pure; inasmuch as the lymphatics, from various parts of the body, are constantly pouring their fluid into the thoracic duct.

From the concurrent testimony of various experimenters, chyle is a liquid of a milky-white appearance; limpid and transparent in herbivorous animals, but opaque in the carnivorous; neither viscid nor glutinous to the touch; of a consistence, varying somewhat according to the nature of the food; a spermatic smell; sweet taste, not dependent on that of the food; neither acid nor alkaline; and of a specific gravity greater than distilled water, but less than the blood. Magendie,[2] Tiedemann and Gmelin,[3] and Müller,[4] however, state it to possess a saline taste; to be clammy on the tongue; and sensibly alkaline. Its milky colour is generally supposed to be owing to oily matter which occurs in it in the form of globules of various sizes, from $\frac{1}{25000}$th to $\frac{1}{20000}$th of an inch in diameter, and which are more abundant in the chyle of man

[1] Syntagm. Anatom., viii. 170.

[2] Précis, &c., ii. 172.

[3] Die Verdauung nach Versuchen, i. 353, Heidelb., 1826; or French translation, by Jourdan, Paris, 1827.

[4] Elements of Physiology, by Baly, p. 258, London, 1838.

and of the carnivora, than in that of the herbivora. Mr. Gulliver[1] has, however, affirmed, that the colour is due to an immense multitude of minute particles, which he regards as forming the matrix or *molecular base* of the chyle. These are generally spherical and extremely small,—their diameter being estimated at from $\frac{1}{18000}$th to $\frac{1}{24000}$th of an inch. They are of a fatty nature, and their number appears to be dependent upon the amount of fatty matter in the food. Their fatty nature is shown by their solubility in ether, and, when the ether evaporates, by their forming drops of oil. As, however, they do not run together, it has been suggested, that each molecule consists of oil coated with albumen, a view which is supported by the fact, that when water or dilute acetic acid is added to chyle, many of the molecules are lost sight of, and oil drops appear in their place; as if the envelopes of the molecules had been dissolved, and their oily contents had run together.[2]

The chemical character of the chyle of animals has been examined by Emmert,[3] Vauquelin,[4] Marcet,[5] Prout,[6] Simon,[7] and Nasse;[8] and is found to resemble greatly that of the blood. In a few minutes after its removal from the thoracic duct it becomes solid; and, after a time, separates, like the blood, into two parts; a coagulum, and a liquid. The coagulum is an opaque white substance; of a slightly pink hue; insoluble in water; but readily soluble in the alkalies, and alkaline carbonates. M. Vauquelin regards it as fibrin in an imperfect state, or as intermediate between that principle and albumen; but M. Brande[9] thinks it more closely allied to the caseous matter of milk than to fibrin. The analyses of Drs. Marcet and Prout agree, for the most part, with that of M. Vauquelin. The existence of fibrin in it can scarcely be doubted.

Like blood, again, chyle often remains for a long time in its vessels without coagulating, but coagulates rapidly on being removed from them.[10]

Dr. Prout has detailed the changes, which the chyle experiences in its passage along the chyliferous apparatus. In each successive stage, its resemblance to blood was found to be increased. Another point of analogy with blood is the fact, observed by Mr. Bauer,[11] and subsequently by MM. Prévost and Dumas,[12] and others, that the chyle, when examined by the microscope, contains globules; differing from those of the blood in their being of a smaller size, the average being $\frac{1}{4800}$th of an inch, and devoid of colouring matter. The nature and source of these globules, as well as of those of the lymph which resemble them in all respects, is not determined. They have been supposed to be the nuclei or primordial cells from which all the tissues originate,[13] and to be the source of the blood globule.

[1] Gerber's General Anatomy, by Gulliver, Appendix, p. 88, London, 1842.
[2] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 207, Philad., 1849.
[3] Annales de Chimie, tom. lxxx. p. 81.
[4] Ibid., lxxx. 113; and Annals of Philosophy, ii. 220.
[5] Medico-Chirurg. Transactions, vol. vi. 618, London, 1815.
[6] Thomson's Annals of Philosophy, xiii. 121, and 263.
[7] Animal Chemistry, Sydenham Soc. edit., p. 354, London, 1845, or Amer. edit., Philad., 1846.
[8] Wagner's Handwörterbuch, u. s. w., i. 235, art. Chyle; and Simon, op. cit.
[9] Phil. Transact. for 1812.
[10] Bouisson, Gazette Médicale de Paris, 1844.
[11] Sir E. Home, op. cit., iii. 25.
[12] Biblioth. Universelle de Genève, p. 221, Juillet, 1821.
[13] Gulliver, in Gerber's Anatomy, p. 83, note.

Although chyle has essentially the same constituents, whatever may be the food taken, and separates equally into a clot and serous portion, the character of the aliment may have an effect upon the relative quantity of those constituents, and thus exert an influence on its composition. That it scarcely ever contains adventitious substances will be seen hereafter; but it is obvious, that if an animal be fed on diet contrary to its nature, the due proportion of *perfect* chyle may not be formed; and that, in the same way, different alimentary articles may be very differently adapted for its formation. MM. Leuret and Lassaigne,[1] indeed, affirm, that in their experiments they found the chyle differ more according to the nature of the food than to the animal species; but that, contrary to their expectation, the quantity of fibrin in it bore no relation to the more or less nitrogenized character of the aliment. They assign it, as constituents, fibrin, albumen, fatty matter, soda, chloride of sodium, and phosphate of lime.

Messrs. Tiedemann and Gmelin have communicated the following data in regard to the influence of diet on the chyle. The experiments were made on dogs, and the chyle was taken from the thoracic duct. *First.* After taking cheese, the chyle coagulated slightly. The clot was little more than a pale red transparent film, and the serum slightly milky. It contained water, 950·3; clot, 1·71: residue of serum, 48·0. *Secondly.* After the use of starch, the chyle was of a pale yellowish-white colour, and coagulated rapidly. It contained water 930·0; clot and residue of serum, 70·0. The clot was of pale red colour. *Thirdly.* After taking flesh, and bread and milk, it was of a reddish-white colour, and coagulated rapidly, the clot being of a pale red tint, and the serum very milky. It consisted of water, 915·3; clot, 2·7; residue of serum, 83·8. *Fourthly.* After the use of milk it presented a milky appearance, and the clot was transparent, and of a pale red colour. *Fifthly.* After bread and milk, it contained water, 961·1; clot 1·9; residue of serum, 37·0. *Sixthly.* After flesh, bread, and milk, it was of a yellowish red colour; coagulated firmly, separating into a bright red clot, and turbid yellow serum; and contained water, 933·5; clot, 5·6; residue of serum, 60·9.[2]

The chief object of Dr. Marcet's experiments was to compare the chyle from vegetable, with that from animal food, in the same animal. The experiments made on dogs led him to the following results. The specific gravity of the serous portion is from 1·012 to 1·021, whether it be formed from animal or vegetable diet. Vegetable chyle, when subjected to analysis, furnishes three times more carbon than animal chyle. The latter is highly disposed to become putrid; and this change generally commences in three or four days; whilst vegetable chyle may be kept for several weeks, and even months, without being putrid.[3] Putrefaction attacks rather the coagulum of the chyle than its serous portion. The chyle from animal food is always milky; and, if kept at rest, an unctuous matter separates from it, similar to cream, which swims on the surface. The coagulum is opaque, and has a rosy tint. On the

[1] Recherches sur la Digestion, Paris, 1825.

[2] Simon, op. cit., p. 358.

[3] M. Thénard has properly remarked, that the difference in the time of putrefaction of these two substances, appears very extraordinary. It is, indeed, inexplicable. Traité de Chimie Elémentaire, &c., 5ème édit., Paris, 1827.

other hand, chyle from vegetable food is almost always transparent, or nearly so, like ordinary serum. Its coagulum is nearly colourless, and resembles an oyster; and its surface is not covered with the substance analogous to cream. M. Magendie,[1] too, remarks, that the proportion of the three substances, into which chyle separates when left at rest;—namely, the fatty substance on the surface, the clot, and the serum, varies greatly according to the nature of the food;—that the chyle, proceeding from sugar, for example, has very little fibrin; whilst that from flesh has more; and that the fatty matter is extremely abundant when the food contains fat or oil; whilst scarcely any is found if the food contains no oleaginous matter. Lastly:—the attention of Dr. Prout[2] has been directed to the same comparison. He found, on the whole, less difference between the two kinds of chyle than had been noticed by Dr. Marcet. In his experiments, the serum of chyle was rendered turbid by heat, and a few flakes of albumen were deposited; but, when boiled, after admixture with acetic acid, a copious precipitation ensued. To this substance, which thus differs slightly from albumen, Dr. Prout gave the inexpressive name of *incipient albumen*. The following is a comparative analysis, by him, of the chyle of two dogs, one of which was fed on animal, and the other on vegetable substances. The quantity of pure albumen, it will be observed, was much less in the latter case.

	Vegetable Food.	Animal Food.
Water	93·6	89·2
Fibrin	0·6	0·8
Incipient albumen	4·6	4·7
Albumen, with a red colouring matter	0·4	4·6
Sugar of milk	a trace.	
Oily matter	a trace.	a trace.
Saline matters	0·8	0·7
	100·0	100·0

The difference between the chyle from food of such opposite character, as indicated by these experiments, is insignificant, and indicative of the great uniformity in the action of the agents of absorption. Researches by Messrs. Macaire and Marcet,[3] tend, indeed, to establish the fact, that both the chyle and the blood of herbivorous and carnivorous quadrupeds are identical in their composition, in as far, at least, as regards their ultimate analysis. They found the same proportion of nitrogen in it, whatever kind of food the animal consumed habitually; and this was the case with the blood, whether of the carnivora or herbivora; but it contained more nitrogen than the chyle. These results are not so singular, now that we know that the animal and vegetable compounds of protein are almost identical in composition. (See page 545.)

All the investigations into the nature of the chyle exhibit the inaccuracy of the view of Roose,[4] that chyle and milk are identical.

[1] Op. citat., p. 174.

[2] Annals of Philosophy, xiii. 22, and Bridgewater Treatise, Amer. edit., p. 272, Philad., 1834.

[3] Mémoir. de la Société de Physique et de l'Histoire Naturelle de Genève, v. 389.

[4] Weber's Hildebrandt's Handbuch der Anatomie, i. 102, Braunschweig, 1830.

With regard to the precise quantity of chyle, formed after a meal, we know nothing definite. When digestion is not going on, there can of course be none formed except from the digestion of the secretions of the digestive tube itself; and, after an abstinence of twenty-four hours, the contents of the thoracic duct are chiefly lymph. During digestion, the quantity of chyle formed will bear some relation to the amount of food taken, the nutritive qualities of the food, and the digestive powers of the individual. M. Magendie,[1] from an experiment made on a dog, estimated, that at least half an ounce was conveyed into the mass of blood, in that animal, in five minutes: and the flow was kept up, but much more slowly, as long as the formation of chyle continued. In experiments on a cat, Professor F. Bidder[2] found the amount that passed through the thoracic duct in the twenty-four hours, to be in proportion to the weight of the body as 1 to 5·34; or about that which—as elsewhere shown—the mass of blood has been generally conceived to bear to the weight of the body. In dogs, the proportion was as 1 to 6·66. It is difficult, however, to establish an average amount where so many elements have to enter into the calculation and so much variation must occur, according to the greater or less amount of aliment taken and numerous other circumstances;[3] but that so large a quantity passes as is stated by these observers, almost exceeds belief.

3. PHYSIOLOGY OF CHYLOSIS.

The facts referred to,—regarding the anatomical arrangement of the chyliferous radicles and mesenteric glands,—will sufficiently account for the obscurity of our views on many points of chylosis. The difficulty in detecting the extremities of the chyliferous radicles has been the source of different hypotheses; and, according as the view of open mouths or of spongy gelatinous tissue has been embraced, the chyle has been supposed to enter immediately into the vessels, or to be received through the medium of this tissue; or, again, to pass through the parietes of the vessels by imbibition. Let it be borne in mind, however, that the action of absorption is seen only by the "mind's eye;" and that chyle does not seem to exist any where but in the chyliferous vessels. In the small intestine, we see a chymous mass, possessing all the properties we have described, but containing nothing resembling true chyle; whilst, in the smallest lacteal that can be detected, it always possesses the same essential properties. Between this imperceptible portion of the vessel, then, and its commencement,—including the latter,—the elaboration must have been effected. MM. Leuret and Lassaigne,[4] indeed, affirm, that they have detected chyle in the chymous mass within the intestine, by the aid of the microscope. They state, that globules appeared in it similar to those that are contained in chyle, and that their dissemination amongst so many foreign matters alone prevents their union in perceptible fibrils. These globules they regard

[1] Op. citat., ii. 183.
[2] Muller's Archiv. für Anat., s. 46, Berlin, 1845.
[3] Prof. Th. L. W. Bischoff, Muller's Archiv., s. 125, Berlin, 1846.
[4] Recherches Physiologiques et Chimiques, pour servir à l'Histoire de la Digestion, p. 60, Paris, 1825.

as true chyle,—for the reason, that they observed similar globules in artificial digestions; and, on the other hand, never detected them in the digestive secretions. In their view, consequently, chyliferous absorption is confined to the separation of chyle, ready formed in the intestine, from the excrementitious matters united with it. But we must have stronger evidence to set aside the overwhelming testimony in favour of an action of selection and elaboration by the absorbents of all organized bodies—vegetable as well as animal. The nutriment of the vegetable may exist in the soil and the air around it; but it is subjected to a vital agency the moment it is laid hold of, and is decomposed to be again combined to form sap. A like action is doubtless exerted by the chyliferous radicles;[1] and hence all the modes of explaining this part of the function, under the supposition of their being passive, mechanical tubes, are inadequate. Boerhaave[2] affirmed, that the peristaltic motion of the intestines has a considerable influence in forcing chyle into the mouths of the chyliferous vessels; whilst Dr. Young[3] is disposed to ascribe the whole effect to capillary attraction; and he cites the lachrymal duct as an analogous case, the contents of which, he conceives,—and we think with propriety,—are entirely propelled in this manner.

The objections to these views, as regards the chyliferous vessels, are sufficiently obvious. The chyle must, according to them, exist in the intestines; and, if that of Boerhaave were correct, we ought to be able to obtain it from the chyme by pressure. As the chyle is not present, ready formed, in the intestine, the explanations by imbibition and by capillary attraction are equally inadmissible. There is no analogy between the cases of the lachrymal duct and the chyliferous vessels; even if it were admitted, that the latter have open mouths, which is not the case. In another part of this work, it was affirmed, that the passage of the tears through the puncta lachrymalia, and along the lachrymal ducts, is one of the few cases in which capillary attraction can be invoked, with propriety, for the explanation of functions executed by the human frame. In that case there is no conversion of the fluid. It is the same on the conjunctiva as in the duct; but, in the case of the chyliferous vessels, a new fluid is formed: there must, therefore, have been an action of selection exerted; and this very action would be the means of the entrance of the new fluid into the mouths of the lacteals. If, therefore, we admit, in any form, the doctrine of capillary tubes, it can only be, when taken in conjunction with that of the elaborating agency. "As far as we are able to judge," says Dr. Bostock,[4] "when particles, possessed of the same physical properties, are presented to their mouths (the lacteals), some are taken up, while others are rejected; and if this be the case, we must conceive, in the first place, that a specific attraction exists between the vessel and the particles, and that a certain vital action must, at the same time, be exercised by the vessel connected with, or depending

[1] F. Arnold, Lehrbuch der Physiologie des Menschen, Zürich, 1836–7; noticed in Brit. and For. Med. Review, Oct., 1839, p. 479.
[2] Prælect. Academ. in Prop. Instit. Rei Med., § 103.
[3] Medical Literature, p. 42, Lond., 1813.
[4] Physiology, edit. cit., 622, Lond., 1836.

upon, its contractile power, which may enable the particles to be received within the vessel, after they have been directed towards it. This contractile power may be presumed to consist in an alternation of contraction and relaxation, such as is supposed to belong to all vessels that are intended for the propulsion of fluids, and which the absorbents would seem to possess in an eminent degree." This is specious; but it would be not the less hypothetical if the chyliferous vessels had open mouths, and we have seen they have not.

By other physiologists, absorption is presumed to be effected by virtue of the peculiar *sensibility* or *insensible organic contractility* or *irritability* of the mouths [?] of the absorbents; but these terms, as M. Magendie[1] has remarked, are the mere expression of our ignorance, regarding the nature of the phenomenon. The separation of the chyle is, doubtless, a chemical process; seeing that there must be both an action of decomposition and recomposition; but it is not regulated solely by the same laws as those that govern inorganic chemistry.

Professor Goodsir,[2] with almost all modern physiologists, has referred the function to the agency of cells. Having fed a dog with oatmeal, butter, and milk, he examined the intestinal villi three hours afterwards; when the chyliferous vessels were turgid with chyle, and the intestine was full of milky chyme mingled with a bilious-looking fluid. In the white portion of the fluid, which was situate principally towards the mucous membrane, numerous epithelium cells were found; some of which had evidently—from their form—been detached from the surface of the villi; whilst others have been thrown off from the interior of the follicles of Lieberkühn. The villi were turgid, and destitute of epithelium except at their bases. Each villus was covered by a very fine, smooth membrane, continuous with what Mr. Bowman terms the "basement membrane" of the mucous surface, which is reflected into the follicles. The villi were semitransparent except at their free or bulbous extremities, where they were white and nearly opaque. The summit of each villus was crowded beneath the enveloping membrane with a number of perfectly spherical vesicles, varying in size from $\frac{1}{1000}$th to $\frac{1}{2000}$th of an inch; the matter in the interior of which had an opalescent milky appearance. At the part where the vesicles approached the granular texture of the substance of the villus, minute granular or oily particles were situate in great numbers. The trunks of two lacteals could be easily traced up the centre of each villus; and as they approached the vesicular mass, they subdivided and looped; but in no instance could they be seen to communicate directly with any of the vesicles. These vesicles, in Mr. Goodsir's opinion, can scarcely be considered in any other light than cells, whose lives have but a very brief duration, which select from, and appropriate the materials in contact with the surface of the villi into their own substance, and then liberate them, by solution or disruption of the cell-wall, in a situation where they can be absorbed by the lacteals. When the intestine contains no more chyme, the developement of new vesicles

[1] Précis, &c., ii. 179.

[2] Edinb. New Philosophical Journal, July, 1842; and Anatomical and Pathological Observations, p. 4, Edinb., 1845.

ceases; the lacteals empty themselves, and the villi become flaccid. During the interval of repose, the epithelium is renewed for the protection of the surface of the villi, and for the secretion function of the follicles of Lieberkühn. It is considered by Mr. Goodsir, that the epithelium cells have their origin in certain nuclei, which he has detected scattered through the basement membrane.

These views were embraced by Dr. Carpenter; but they are by no means established. It is denied, indeed, by Reichert,[1] from his own and Bidder's observations, that the epithelium is ever so shed from the digestive canal, in or after any act of digestion, as to leave any portion of the subjacent mucous membrane uncovered or raw; and Prof. E. H. Weber[2] distinctly observed the chyliferous vessels filled with chyle, although the mucous membrane was covered with epithelium. The materials of the chyle, therefore, to enter the vessels must have passed through the epithelium. During absorption, he noticed the prismatic cells of the cylinder epithelium experiencing change of form and colour, and in rabbits and frogs becoming tumid, and containing chyle corpuscles. In man, beneath the epithelium is a second layer of cells, which are neither conical, cylindrical, nor prismatic, but round; many of which are filled with an opaque white; and others with a transparent, oleaginous fluid; so that different cells appeared to absorb different fluids.

It has already been said, that chyle always possesses the same essential properties; that it may vary slightly according to the food, and the digestive powers of the individual; but rarely if ever contains any adventitious substance,—the function of the chyliferous vessels being restricted to the formation of chyle. The facts and arguments, in favour of this view of the subject, will be given hereafter.

The course of the chyle is, as we have described, along the chyliferous vessels, and through the mesenteric glands into the receptaculum chyli or commencement of the thoracic duct; along which it passes into the subclavian vein. The chief causes of its progression are,—first of all, the inappreciable action, by which the chyliferous vessels form and receive the chyle into them. This formation being continuous, the fresh portions must propel those already in the vessels towards the mesenteric glands, in the same way as the ascent of sap in plants, during the spring, appears to depend on the constant absorbing action of the roots.[3] It is probable, too, that the vessels themselves are contractile:[4] such is the opinion of Messrs. Sheldon,[5] Schneider, Cruikshank,[6] and J. Müller. M. Mandl[7] affirms, that it can no longer be doubted; and that the irritability continues even for several hours after death. M. Mojon[8] considers, that when the longitudinal fibres, which he has observed in the lymphatics, contract, they draw one sphincter nearer to another, whilst the oblique fibres diminish the diameter. All

[1] Müller's Archiv., 1844. [2] Ibid., s. 401, Berlin, 1847.
[3] Breschet, Le Système Lymphatique, Paris, 1836.
[4] Müller's Handbuch, u. s. w., and Baly's translation, i. 284, Lond., 1838.
[5] History of the Absorbent System, p. 28, Lond., 1784. [6] Op. citat., c. 12.
[7] Manuel d'Anatomie générale, p. 211, Paris, 1843.
[8] Journ. de la Société des Sciences Physiques, etc., Nov., 1833.

these fibres, taking their *point d'appui* in the circular fibres, dilate the superior sphincters by drawing the circumference downwards. By this method, the fluid that enters a lymphatic irritates the vessel, which contracts upon itself, diminishes its cavity, and sends on the fluid through the open sphincter. A kind of peristaltic action, he conceives,—and in this view he is confirmed by MM. Lacauchie,[1] Gruby, and Delafond,[2]—exists in the lymphatics similar to that of the intestines, which may be observed very distinctly, he says, in the lacteal vessels of the mesentery of animals, if opened two or three hours after they have been well fed.

Moreover, that the lacteals and lymphatics are possessed of a power of contraction is corroborated—it is argued—by the following reasons. *First.* They are small; and tonic contractions are generally admitted in all capillary vessels. *Secondly.* The ganglions or glands, which cut them at intervals, would destroy the impulse given by the first action of the radicles; and hence require some contraction in the vessels to transport the chyle from one row of these ganglions to another. *Thirdly.* If a chyliferous vessel be opened in a living animal, the chyle spirts out, which could not be effected simply by the absorbent action of the chyliferous radicles; and, *Fourthly*, in a state of abstinence, these vessels are found empty; proving, that notwithstanding there has been an interruption to the action of chylous absorption, the whole of the chyle has been propelled into the receptaculum chyli. It is obvious, however, that most of these reasons would apply as well to the elasticity as to the muscularity of the outer coat of these vessels.[3] A more forcible argument is derived from an experiment by Lauth.[4] He killed a dog towards the termination of digestion; and immediately opened its abdomen, when he found the intestines marbled, and the chyliferous vessels filled with chyle. Under the stimulation of the air, the vessels began to contract, and, in a few minutes, were no longer perceptible. The result he found to be the same, whenever the dissection was made within twenty-four hours after death; but, at the end of this time, the irritability of the vessels was extinct; and they remained distended with chyle, notwithstanding the admission of air. These experiments lead to a deduction, in the absence of less direct proof, scarcely doubtful;—that the chyliferous vessels possess a contractile action, by the aid of which the chyle is propelled along the vessels. In addition to these propelling causes, the pulsation of the arteries in the neighbourhood of the vessels, and the pressure of the abdominal muscles in respiration have been invoked. The former has probably less effect than the latter. It is not, indeed, easy to see how it can be possessed of any. Of the agency of the latter we have experimental evidence. If the thoracic duct be exposed in the neck of a living animal, and the course of the chyle be observed, it will be found accelerated at the time of inspiration, when the depressed diaphragm forces down the viscera, or when the abdomen of the animal is compressed by the hands. We shall find, too, hereafter, that the mode in which the thoracic duct opens into the

[1] Comptes Rendus, 15 Mai, 1843.
[2] Ibid., 5 Juin, 1843.
[3] Adelon, Physiologie, etc., iii. 31.
[4] Essai sur les Vaisseaux Lymphat., Strasb., 1824.

subclavian exerts considerable effect on the progress of the chyle. We have reason to believe that its course is slow. It has been already stated, that in an experiment on a dog, which had eaten animal food at discretion, M. Magendie[1] found half an ounce of chyle discharged from an opening in the thoracic duct in five minutes. Still, as he judiciously remarks, the velocity will be partly dependent upon the quantity of chyle formed. If much enters the thoracic duct, it will probably proceed faster than under opposite circumstances. In the commencement of the thoracic duct it becomes mixed with lymph; and under the head of lymphatic absorption we shall show how they proceed together into the subclavian, and the effect produced by the circumstances under which the thoracic duct opens into that venous trunk.

It has been a subject of inquiry, whether chyle varies materially in different parts of its course; and what is the precise modification, impressed upon it by the action of the mesenteric glands. The experiments of Reuss, Emmert,[2] and others, seem to show, that when taken from the intestinal side of the glands it is of a yellowish-white colour; does not become red on exposure to the air, and coagulates but imperfectly, depositing only a small, yellowish pellicle. It is said, indeed, that chyle, drawn from the chyliferous vessels, which traverse the intestinal walls, contains albumen in a state of solution, but no fibrin, and abounds in oleaginous matter; whilst that from the other side of the glands, and near the thoracic duct, is of a reddish hue: contains chyle globules, coagulates entirely, and separates into a clot and serum. M. Vauquelin,[3] too, affirms, that it acquires a rosy tint as it advances in the apparatus; and that the fibrin becomes gradually more abundant. These circumstances have given rise to the belief, that as it proceeds it becomes more and more animalized, or transformed into the nature of the being. This effect has generally been ascribed to the mesenteric glands; and it has been presumed by some to be produced by the exhalation of a fluid into their cells from the numerous bloodvessels with which they are furnished. Others, again, consider, that the veins of the glands remove from the chyle every thing that is noxious; or purify it. From the circumstance, that the rosy colour is more marked on the thoracic, than on the intestinal side of the glands; that the fluid is richer in fibrin after having passed through those glands; and that the rosy colour and fibrin are less when the animal has taken a large proportion of food, MM. Tiedemann and Gmelin[4] infer, that it is to the action of the glands, that the chyle owes those important changes in its nature;—the fluid, in its passage through them, obtaining, from the blood circulating in them, new elements, which animalize it.

There is much probability in the view, that some nitrogenized material is secreted from the lining membrane of the chyliferous vessels, in the mesenteric glands especially, through the agency of the nucleated cells described by Professor Goodsir, which may be a great agent in the changes effected on the chyle in its course. At the same time—as

[1] Précis, &c., ii. 183.
[2] Reil's Archiv., viii. s. 2; and Annales de Chimie, lxxx. 81.
[3] Annales de Chimie, lxxxi. 113; and Annals of Philosophy, ii. 220.
[4] Die Verdauung nach Versuchen, u. s. w., or Jourdan's translat., Paris, 1827.

has been well observed[1]—an important source of fallacy attends all deductions founded upon the differences observed in the chyle in the several parts of its course through the lacteals,—which is, that we cannot be at all sure how far this may not be dependent upon an actual interchange of ingredients with the blood, by imbibition through the very thin parietes of the contiguous vessels. The whole question, as Dr. Carpenter properly remarks, offers a wide scope for farther inquiry.

The following table, slightly modified from one by Gerber,[2] exhibits concisely the relative proportions of the three main ingredients of the chyle—fat, albumen, and fibrin—in various parts of the absorbent system; and affords some idea of its change in the process of assimilation.

I. In the afferent or peripheral lacteals (from the intestines to the mesenteric glands).	*Fat* in maximum quantity (numerous fat or oil globules). *Albumen* in minimum quantity (few or no *chyle corpuscles*). *Fibrin* almost entirely wanting.
II. In the efferent or central lacteals (from the mesenteric glands to the thoracic duct).	*Fat* in medium quantity (fewer oil globules). *Albumen* in maximum quantity (*chyle corpuscles* very numerous, but imperfectly developed). *Fibrin* in medium quantity.
III. In the thoracic duct.	*Fat* in minimum quantity (fewer or no oil globules). *Albumen* in medium quantity (*chyle corpuscles* numerous and more distinctly cellular). *Fibrin* in maximum quantity.

In another place, various hypotheses, that have been indulged regarding the functions of the spleen, will be noticed. It is proper, however, to refer, here, to one which has been proposed by MM. Tiedemann and Gmelin. They consider the organ a dependent ganglion of the absorbent system, which prepares a fluid destined to be mixed with the chyle to effect its animalization; and assert, that the chyle coagulates little or not at all before it has passed through the mesenteric glands; but, after this, fibrin begins to appear, and is much more abundant after the addition of the lymph from the spleen, which contains a large quantity of fibrin. Before passing the mesenteric glands, the chyle contains no red particles; but it does so immediately afterwards, and more particularly after it is mixed with the lymph from the spleen, which abounds with them, and with fibrin. M. Voisin,[3] who, as we have seen, considers that the chyliferous vessels ramify in the substance of the liver, is of opinion that, by the action of the liver, a species of purification is produced in the chyle, by which the latter is better fitted to mingle with, and form part of, the blood; but neither his anatomical nor physiological views on the subject have met with much countenance.

Prior to the discovery of the chyliferous vessels, the mesenteric veins were regarded as agents of chylous absorption; and as these veins terminate in the vena portæ, which is distributed to the liver, this last was considered the first organ of sanguification; and to impress upon the chyle a primary elaboration. In this view, the great size of the organ compared with the small quantity of bile furnished by it, and the exception, which the mesenteric veins and vena portæ present to the rest of

[1] Carpenter, Human Physiology, 2d Amer. edit., p. 426, Philad., 1845.
[2] Ibid., p. 427.
[3] Nouvel Aperçu sur la Physiologie du Foie, &c., Paris, 1833.

the venous system,—as well as the large size of the liver in the fœtus, although not effecting any biliary secretion, and the fact of its receiving immediately the nutritive fluid from the placenta were accounted for. The idea of the agency of the mesenteric veins is now nearly exploded, but not altogether so. There are yet physiologists, and of no little eminence, who esteem them participators in the functions of chylosis with the chyliferous vessels themselves.

Some of the arguments, based on fallacious data, used by these gentlemen, are:—*First.* The mesenteric veins form as much an integrant part of the villi of the intestine as the chyliferous vessels; and they have also, free orifices [?] in the cavity of the intestine. Lieberkühn,[1] by throwing an injection into the vena portæ, observed the fluid ooze out of the villi of the intestine; and M. Ribes[2] obtained the same result by injecting spirit of turpentine coloured black. These experiments—it need hardly be said—are insufficient to establish the fact of open mouths. Situate, as those vessels are, in an extremely loose tissue, which affords them but little support, the slightest injecting force might be expected to rupture them. *Secondly.* Chyle has often been found in the mesenteric veins. Swammerdam asserts, that, having placed a ligature around these veins in a living animal, whilst digestion was going on, he saw whitish, chylous striæ in their blood; and Tiedemann and Gmelin affirm, that they have often, in their experiments, observed the same appearance. If the fact of the identity of these striæ with chyle were well established, we should have to bend to the weight of evidence. This is not, however, the case. No other reason for the belief is afforded than their colour. The arguments against the mesenteric veins having the power of forming chyle we think irresistible. A distinct apparatus exists, which scarcely ever contains any thing but chyle; and consequently, it would seem unnecessary, that the mesenteric veins should participate in the function, especially as the fluid which circulates in them is most heterogeneous; and, as we shall see, a compound of various adventitious and other absorptions. Granting, however, that these striæ are true chyle, it would by no means follow absolutely, that it should be formed by the mesenteric veins. A communication may exist between the chyliferous vessels and these veins. Wallæus[3] asserts, that having placed a ligature on the lymphatic trunks of the intestine, chyle passed into the vena portæ. Rosen, Meckel,[4] and Lobstein affirm, that by the use of injections they detected this inosculation. Lippi[5] states, that the chyliferous vessels have numerous anastomoses with the veins, not only in their course along the mesentery before they enter the mesenteric glands, but also in the glands themselves. Tiedemann and Gmelin concur in the existence of this last anastomosis, and MM. Leuret and Lassaigne found that a ligature applied round the vena portæ occasioned the reflux of blood into the tho-

[1] Dissert. de Fabric. Villor. Intestin., Lugd. Bat., 1745.
[2] Mémoir. de la Société Médicale d'Emulation, viii. 621.
[3] Medica Omnia, &c., ad Chyli et Sanguinis Circul., Lond., 1660.
[4] Diss. Epist. ad Haller. de Vasis Lymph., &c., Berol., 1757; Nov. Exper. de Finibus Venarum et Vas. Lymph., Berol., 1772; and Manuel d'Anatomie, &c., French edit., by Jourdan, i. 179.
[5] Illustrazioni Fisiologiche e Patologiche del Sistema Linfatico-Chilifero, Firenze, 1825.

racic duct. Professors Meckel, E. H. Weber, Rudolphi, and J. Müller doubt, however, the existence of an actual open communication between the lymphatics and minute veins in the glands. Meckel states, as a reason for his questioning this, that when the seminal duct of the epididymis of the dog is injected, the veins also are filled; and Müller[1] observes, that when glands are injected from their excretory duct, the small veins of the gland also frequently become filled with mercury; and the cases in which this occurred to him were always those in which the ducts had not been well filled,—their acini not distended. *Thirdly*. That the ligature of the thoracic duct has not always induced death, or has not induced it speedily; and, consequently, the thoracic duct is not the only route by which the chyle can pass to be inservient to nutrition. In an experiment of this kind by M. Duverney, the dog did not die for fifteen days. M. Flandrin repeated it on twelve horses, which appeared to eat as usual, and to maintain their flesh. On killing and opening them a fortnight afterwards, he satisfied himself that the thoracic duct was not double. Sir Astley Cooper performed the experiment on several dogs: the majority lived longer than a fortnight, and none died in the first two days; although, on dissection, the duct was found ruptured, and chyle effused into the abdomen. The experiments of M. Dupuytren have satisfactorily accounted for these different results. He tied the thoracic duct in several horses. Some died in five or six days, whilst others continued apparently in perfect health. In those that died in consequence of the ligature, it was impossible to throw any injection from the lower part of the duct into the subclavian. It was, therefore, presumable, that the chyle had ceased to be poured into the blood, immediately after the duct was tied. On the other hand, in those that remained apparently unaffected, it was always easy to send mercurial or other injections from the abdominal portion of the duct into the subclavian. The injections followed the duct until near the ligature, when they turned off, and entered large lymphatic vessels, which opened into the subclavian; so that, in these cases, the ligature of the thoracic duct did not prevent the chyle from passing into the venous system; and thus we can understand why the animals should not have perished.[2]

From every consideration, then, it appears that the chyliferous vessels are the sole organs concerned in chylosis; and we shall see presently, that they refuse the admission of other substances, which must, consequently, reach the circulation through a different channel.

The views of MM. Bouchardat and Sandras—who believe, that the absorption of the nutritive portion of most aliments takes place in the stomach,—fatty matters only being absorbed by these vessels, and that they moreover absorb a fluid of an alkaline character designed to neutralize the acidity developed in the stomach during digestion, as well as those of Matteucci and Bertrand in regard to the absorption of the same substances, have been given already.

[1] Handbuch, u. s. w.; and Baly's translation, p. 273, Lond., 1838.
[2] Richerand's Elémens de Physiologie, edit. cit., p. 90.

b. *Absorption of Drinks.*

It has been stated, that a wide distinction exists between the gastric and intestinal operations that are necessary in the case of solid and liquid food. Whilst the former is converted into chyme and passes into the small intestine, to have its chylous part separated from it; the latter is usually absorbed from the stomach or small intestine.

The chyliferous vessels, we have seen, are agents and exclusive agents of the absorption of chyle—the nutritive product from the digestion of solids. What, then, are the agents of the absorption of liquids? There are but two sets of vessels on which we can rest for a moment. These are the lacteals or lymphatics of the digestive tube; and the veins of the same canal. But, it has been seen, the chyliferous vessels refuse the admission of everything but chyle. It would necessarily follow, then, that the absorption of liquids must be a function of the veins. Such is the conclusion of most physiologists, and on inferences that are logical. The view is not, however, universally admitted; some assigning the function exclusively to the lacteals; others sharing it between them and the veins. Let us inquire into the facts and arguments adduced in support of these different opinions. The advocates for the exclusive agency of the chyliferous vessels affirm, *First*, That whatever is the vascular system, that effects the absorption of drinks, it must communicate freely with the cavity of the intestine; and that the chyliferous vessels do this. *Secondly*, That this system of vessels is the agent of chylous absorption:—a presumption, that it is likewise the agent of the absorption of drinks. *Thirdly*, That every physiologist, who has examined the chyle, has described its consistence to be in an inverse ratio with the quantity of drink taken; and, lastly, that when coloured and odorous substances have passed into the intestine, they have been found in the chyliferous vessels and not in the mesenteric veins. The experiments, adduced in favour of this last position are, however, so few and inadequate, that it is surprising they could have, for a time, so completely overturned the old theory. This effect was greatly aided by the zeal and ability of the Hunters, and of the Windmill Street School in general, who were the great improvers of our knowledge regarding the anatomy of the lymphatic system. John Hunter,[1]—who was one of the first that positively denied absorption by the veins, and maintained that of the lymphatics,—instituted the following ingenious and imposing experiment. He opened the abdomen of a living dog; laid hold of a portion of intestine, and pressed out the matters it contained with his hand. He then injected warm milk into it, which he retained by means of ligatures. The veins, belonging to the portion of intestine, were emptied of their blood by puncturing their trunks; and were prevented from receiving fresh blood, by the application of ligatures to the corresponding arteries. The intestine was returned into the cavity of the abdomen; and, in the course of half an hour, was again withdrawn and scrupulously examined; the veins were still found empty, whilst the

[1] Observations on certain parts of the Animal Economy, by John Hunter, F. R. S., with notes by Richard Owen, F. R. S., Bell's Library edit., p. 307, Philad., 1840.

chyliferous vessels were full of a white fluid. Mr. Hunter subsequently repeated the experiment with odorous and coloured substances, but without being able to detect them in the mesenteric veins. It may be remarked, also, that Musgrave,[1] Lister,[2] Blumenbach,[3] Seiler and Ficinus assert,[4] that they have detected substances, which had been thrown into the intestines of animals, in the chyle of the thoracic duct. The experiments of Hunter, however, are those, on which the supporters of this view of the question principally rely.

Physiologists, who believe in the absorption of liquids by the mesenteric veins, adduce similar arguments and much more numerous experiments. They affirm, that the mesenteric veins, like the chyliferous vessels, form constituent portions of the villi;—that if the chyliferous system is manifestly an absorbent apparatus, the same may be said of the venous system;—that if the chyle has appeared more fluid after much drink has been taken, the blood of the mesenteric veins was seen by Boerhaave to be more fluid under like circumstances; and, lastly, against the experiments of Hunter, numerous others have been cited, showing clearly, that liquids, injected into the intestine, have been found in the mesenteric veins, whilst they could not be detected in the chyliferous vessels.

To the first experiment of Hunter it has been objected;—that in his time the art of performing physiological experiments was imperfect; and that, in order to deduce useful inferences from it, we ought to know, whether the animal was fasting, or digestion was going on at the time it was opened; that the lymphatics ought to have been examined at the commencement of the experiment, to see whether they were full of chyle, or empty; as well as the milk, to notice whether it had experienced any change during its stay in the intestine; and lastly, that the reasons ought to have been assigned for the belief, that the lacteals were filled with milk at the end of the experiment, and not with chyle. Moreover, the experiment has been repeated several times by MM. Flandrin and Magendie,[5]—careful and accurate observers,—yet, in no case, was the milk found in the chyliferous vessels. The first experiment of Hunter cannot, therefore, be looked upon as satisfactory. Some source of fallacy must have occurred, otherwise a repetition of the experiment should have been attended with like results. We shall find, hereafter, that in another experiment, by that distinguished individual, a source of illusion existed, of which he was not unaware, that was sufficient to account for the appearance he noticed.

The experiments of Hunter with odorous and coloured substances have been repeated by many physiologists, and found even less conclusive than that with the milk. M. Flandrin, who was professor in the Veterinary School at Alfort, in France, thought that he could detect, in horses, an herbaceous odor of the blood of the mesenteric veins, but not of the chyle. He gave a horse a mixture of half a pound of honey, and the same quantity of asafœtida; and, whilst the smell of the latter

[1] Philosoph. Transact. for 1701, p. 996.
[2] Philosoph. Transact., 1701, p. 819.
[3] Institut. Physiol., § 422.
[4] Journal Complément., xviii. 327.
[5] Précis, &c., edit. citat., ii. 201.

was distinctly perceptible in the venous blood of the stomach and intestine, no trace of it existed in arterial blood and chyle. Sir Everard Home[1] having administered tincture of rhubarb to an animal, round whose thoracic duct he had placed a ligature, found the rhubarb in the bile and urine. M. Magendie gave to dogs, whilst digesting, a quantity of alcohol diluted with water; and solutions of camphor, and other odorous fluids: on examining the chyle, half an hour afterwards, he could not detect any of those substances; but the blood of the mesenteric veins exhaled the odour, and afforded the substances by distillation. He gave to a dog four ounces of a decoction of rhubarb; and, to another, six ounces of a solution of prussiate of potassa in water. Half an hour afterwards, no trace of these substances could be detected in the fluid of the thoracic duct; whilst they could be in the urine. On another dog, he tied the thoracic duct, and gave it two ounces of a decoction of nux vomica. Death occurred as speedily as in an animal in which the thoracic duct was pervious. The result was the same, when the decoction was thrown into the rectum, where no proper chyliferous vessels exist. Having tied the pylorus in dogs, and conveyed fluids into their stomachs, absorption equally took place, and with the same results. Lastly, with M. Delille,[2] he performed the following experiment on a dog, which had eaten a considerable quantity of meat, in order that the chyliferous vessels might be easily perceived. An incision was made through the abdominal parietes; and a portion of the small intestine drawn out, on which two ligatures were applied at a short distance from each other. The lymphatics, which arose from this portion of the intestine, were very white, and apparent from the chyle that distended them. Two ligatures were placed around each of them; and they were divided between the ligatures. Every precaution was taken, that the portion of intestine drawn out of the abdomen should have no connexion with the rest of the body by lymphatics. Five mesenteric arteries and veins communicated with this portion of the intestine. Four of the arteries and as many veins were tied, and cut in the same manner as the lymphatics. The two extremities of the portion of intestine were now divided, and separated entirely from the rest. A portion, an inch and a half long, thus remained attached to the body by a mesenteric artery and vein only. These two vessels were separated from each other by a distance of four fingers' breadth; and the areolar coat was removed to obviate the objection, that lymphatics might exist in it. Two ounces of a decoction of nux vomica were now injected into this portion of intestine, and a ligature was applied to prevent the exit of the injected liquid. The intestine, surrounded by fine linen, was replaced in the abdomen; and, in six minutes, the effects of the poison were manifested with their ordinary intensity:—every thing occurred as if the intestine had been in its natural condition. M. Ségalas[3] performed a similar experiment, leaving the intestine, however, communicating with the rest of the body by chyliferous vessels only. On injecting a solution of half a drachm of alcoholic extract of nux vomica into the intestine; the poisoning, which, in the experiment of M. Magendie,

[1] Lectures on Comparative Anatomy, i. 221, Lond., 1814.
[2] Précis, &c., ii. 203.
[3] Magendie's Journal de Physiologie, tom. ii.; and Précis, &c., ii. 208.

took effect in six minutes, had not occurred at the expiration of half an hour; but when one of the veins was untied and the circulation re-established, it supervened immediately. Westrumb[1] mixed rhubarb, turpentine, indigo, prussiate of potassa, and acetate of lead with the food of rabbits, sheep, and dogs. They were detected in the veins of the intestines and in the urine, but not in the chyle. The same facts were observed by Mayer[2] when rhubarb, saffron, and prussiate of potassa were introduced into the stomach. MM. Tiedemann and Gmelin likewise observed that the absorption of different colouring and odorous substances from the intestinal canal was effected exclusively by the veins. Indigo, madder, rhubarb, cochineal, litmus, alkanet, camboge, verdigris, musk, camphor, alcohol, spirits of turpentine, Dippel's animal oil, asafœtida, garlic, the salts of lead, mercury, iron, and baryta, were found in the venous blood, but never in the chyle. The prussiate of potassa and sulphate of potassa were the only substances, which, in their experiments, had entered the chyliferous vessels.

Such are the chief facts and considerations on which the believers in the chyliferous absorption and venous absorption of drinks rest their respective opinions. The strength is manifestly with the latter. Let it be borne in mind, that no sufficient experiments have been made, to encourage the idea, that any thing is contained in the chyliferous vessels except chyle; and that nearly all are in favour of absorption by the mesenteric veins. An exception to this, as regards the chyliferous and lymphatic vessels, seems to exist in the case of certain salts. The prussiate and the sulphate of potassa—we have said—were detected in the thoracic duct by MM. Tiedemann and Gmelin; the sulphate of iron and the prussiate of potassa were found there by Messrs. Harlan, Lawrence, and Coates[3] of Philadelphia; and the last of these salts by Dr. Macneven of New York. "I triturated," says Dr. Macneven,[4] "one drachm of crystallized hydrocyanate of potassa with fresh butter and crumbs of bread, which being made into a bolus the same dog swallowed and retained. Between three and four hours afterwards, Dr. Anderson bled him largely from the jugular vein. A dose of hydrocyanic acid was then administered, of which he died without pain, and the abdomen was laid open. The lacteals and thoracic duct were seen well filled with milk-white chyle. On scratching the receptaculum, and pressing down on the duct, nearly half a teaspoonful of chyle was collected. Into this were let fall a couple of drops of the solution of permuriate of iron, and a deep blue was the immediate consequence." Professor J. Muller[5] placed a frog with its posterior extremities in a solution of prussiate of potassa, which reached nearly as high as the anus, and kept it so for two hours. He then carefully washed the animal, and having wiped the legs dry tested the lymph taken from under the skin with a persalt of iron; it immediately assumed a bright blue colour, while that of the serum of the blood was scarcely affected by the test. In a second

[1] De Phænomenis, quæ ad Vias sic dictas Lotii clandestinas referuntur, Gotting., 1819.
[2] Meckel's Archiv., Band. iii.
[3] Philad. Journ. of Med. and Phys. Sciences, vol. ii.; and Harlan's Medical and Physical Researches, p. 458, Philad., 1835.
[4] New York Med. and Phys. Journ., June, 1822.
[5] Handbuch der Physiologie, u. s. w. Baly's translation, p. 279, Lond., 1838.

experiment, in which the frog was kept only one hour in the solution, the salt could not be detected in the lymph. These exceptions are strikingly corroborative of the rule. Of the various salts employed, only those mentioned appear to have been detected in the chyle of the thoracic duct. It is, therefore, legitimately presumable, that they entered adventitiously, and probably by simple mechanical imbibition:—the mode in which venous absorption seems to be effected.

The property of imbibition, possessed by animal tissues, has already been the subject of remark (page 65). It was then shown, that they are not all equally penetrable; and that different fluids possess different penetrative powers. This view is confirmed by the experiments of MM. Tiedemann and Gmelin on the subject under discussion. Although various substances were placed in the same part of the intestinal canal, they were not all detected in the blood of the same vessels. Indigo and rhubarb, for example, were found in the blood of the vena portæ. Camphor, musk, spirit of wine, spirit of turpentine, oil of Dippel, asafœtida, garlic, not in the blood of the intestines, but in that of the spleen and mesentery; prussiates of iron, lead, and potassa in that of the veins of the mesentery; those of potassa, iron, and baryta in that of the spleen ; prussiate of potassa, and sulphates of potassa, iron, lead, and baryta in that of the vena portæ as well as in the urine; whilst madder and camboge were found in the latter fluid only.

Experiments by MM. Flandin and Danger[1] confirm the general rule of the absorption of poisons from the digestive canal by the branches of the vena portæ, and the diversity of locality in which they are met with. Their latest examinations were made on the absorption of the salts of lead, which they detected in the digestive tube, liver, spleen, kidneys, and lungs, but not in the blood, heart, brain, muscles, or bones.

The evidence in favour of the action of the chyliferous vessels being restricted to the absorption of chyle, whilst the intestinal veins take up other matters, is not, however, considered by some to be as inconclusive as it is by us. M. Adelon,[2] for example, concludes, that, as the sectators, on both sides, employ absolutely the same arguments, we are compelled to admit, that the two vascular systems are under exactly similar conditions; and both, consequently, participate in the function. We have seen, that whatever may be the similarity of arguments, the facts are certainly not equal.[3] It is proper, however, to remark, that chemical analysts experience great difficulty in detecting inorganic substances when these are mixed with certain of the compounds of organization; and this may account for such substances not having been discovered in the thoracic duct, even when present there.

With regard to the mode in which the absorption of fluids is effected, a difference of opinion has existed, and chiefly as regards the question,—whether, as in the case of the chyle, any vital elaboration be concerned, or whether the fluid, when it attains the interior of the vessel, be the same as without. The arguments in favour of these different

[1] Gazette Médicale. 3 Févr., 1844.
[2] Physiologie de l'Homme, edit. cit., iii. 111.
[3] Bostock's Physiol., 3d edit., p. 607, Lond., 1836.

views will be detailed under the head of Venous Absorption. We may merely observe, at present, that water,—the chief constituent of all drinks,—is an essential component of every circulating fluid;—that we have no evidence that any action of elaboration is exerted upon it: and that the ingenious and satisfactory experiments of Prof. J. K. Mitchell,[1] of Philadelphia, have shown, that it penetrates most, if not all, animal tissues better than any other liquid; and, consequently, passes through them to accumulate in any of its own solutions. It is probably in this way,—that is, by imbibition,—that all venous absorptions are effected.

But it has been said:—if fluids pass so readily through the coats of the veins,—by reason of the extensive mucous surface, with which they come in contact, a large quantity of extraneous and heterogeneous fluid must enter the abdominal venous system when we drink freely, and the composition of the blood be consequently modified; and, if it should arrive, in this condition, at the heart, the most serious consequences might result. It has, indeed, been affirmed by a distinguished member of the profession[2] in this country, in a more ingenious than forcible argument to support a long-cherished—but now almost universally abandoned—hypothesis, that "it must at least be acknowledged, that no substance, in its active state, does reach the circulation, since it is shown, that a small portion even of the mildest fluid, as milk or mucilage, oil or pus, cannot be injected into the bloodvessels without occasioning the most fatal consequences." But the effects are here greatly dependent on the mode in which the injection is made. If a scruple of bile be sent forcibly into the crural vein, the animal generally perishes in a few moments. The same occurs, if a quantity of atmospheric air be rapidly introduced into a venous trunk. The animal, according to Sir Charles Bell,[3] dies in an instant, when a very little air is blown in;—and there is no suffering nor struggle, nor any stage of transition, so immediately does the stillness of death take possession of every part of the frame. In this way, according to Beauchêne, Larrey, Dupuytren, Warren of Boston, Mott and Stevens of New York, Delpech, and others, operations at times prove fatal;—the air being drawn in by the divided veins. If, however, the scruple of bile, or the same quantity of atmospheric air be injected into one of the branches of the vena portæ, no apparent inconvenience is sustained. M. Magendie[4] concludes, from this fact, that the bile and atmospheric air, in their passage through the myriads of small vessels into which the vena portæ divides and subdivides in the substance of the liver, become thoroughly mixed with the blood, and thus arrive at the vital organs in a condition to be unproductive of mischief. This view is rendered the more probable by the fact, that if the same quantity of bile or of air be injected very slowly into the crural vein, no perceptible inconvenience is sustained. Dr. Blundell[5] injected in this manner five drachms into the femoral vein of a very small dog, with only tempo-

[1] American Journal of the Medical Sciences, vii. 44, 58.
[2] Chapman, Elements of Therapeutics, 6th edit., p. 47, Philad., 1831.
[3] Animal Mechanics, P. ii. p. 42, London, 1829.
[4] Précis Elémentaire, 2de édit., ii. 433. [5] Medico-Chirurg. Trans. for 1818, p. 65.

rary inconvenience; and, subsequently, three drachms of expired air, without much temporary disturbance; and M. Lepelletier[1] affirms, that in the amphitheatre of the *Ecole Pratique* of Paris, in the presence of upwards of two hundred students, he injected thrice into the femoral vein of a dog, of middle size, at a minute's interval, three cubic inches of air, without observing any other effect than struggling, whining, and rapid movements of deglutition; and these phenomena existed only whilst the injection was going on. Since that he has often repeated the experiment with identical results,—"proving," he observes, "that the deadly action of the air is, in such case, mechanical, and it is possible to prevent the fatal effects by injecting it so gradually, that the blood has power to disseminate, and perhaps even to dissolve it with sufficient promptitude to prevent its accumulation in the cardiac cavities." From the experiments of Mr. Erichsen, however, the cause of death in such cases, would appear to be asphyxia.

As liquids are frequently passed off by the urinary organs soon after they have been swallowed, it has been believed by some,—either that there are vessels which form a direct communication between the stomach and bladder; or that a transudation takes place through the parietes of the stomach and intestine, and that the fluids proceed through the intermediate areolar tissue to the bladder. Both these views, we shall hereafter show, are devoid of foundation.

In animals, in which the cutis vera is exposed, or the cuticle very thin, nutritive absorption is effected through that envelope. In the polypi, medusæ, radiaria, and vermes, absorption is active, and according to Zeder and Rudolphi,[2] entozoa, that live in the midst of animal humours, imbibe them through the skin. A few years ago, Jacobson[3] instituted experiments on the absorbing power of the helix of the vine (*Limaçon des vignes*). A solution of prussiate of potassa was poured over the body. This was rapidly absorbed, and entered the mass of blood in such quantity, that the animal acquired a deep blue colour when sulphate of iron was thrown upon it. In the frog, toad, salamander, &c., cutaneous absorption is so considerable, that occasionally the weight of water, taken in this way, is equal to that of the whole body. We shall see, hereafter, that the nutrition of the fœtus in utero is mainly, perhaps, accomplished by nutritive absorption effected through the cutaneous envelope.

II. ABSORPTION OF LYMPH OR LYMPHOSIS.

This function is effected by agents, that strongly resemble those concerned in the absorption of chyle. One part of the vascular apparatus is, indeed, common to both,—the *thoracic duct*. We are much less acquainted, however, with the physiology of lymphatic, than of chyliferous, absorption.

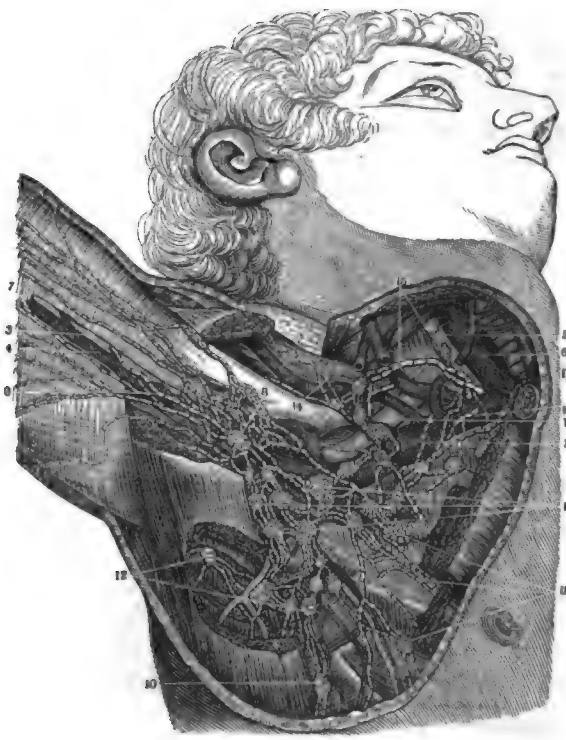
[1] Physiologie Médicale et Philosophique, i. 494, Paris, 1831.
[2] Entozoorum Histor., i. 252, 275, Berlin, 1829.
[3] Mémoir. de l'Acad. des Sciences de Berlin, 1825, and Tiedemann, Traité Complet de Physiologie de l'Homme, edit. Fr., p. 242, Paris, 1831.

1. ANATOMY OF THE LYMPHATIC APPARATUS.

The lymphatic apparatus consists of lymphatic vessels, lymphatic glands or ganglia, and thoracic duct. The latter, however, does not form the medium of communication between all the lymphatic vessels and the venous system.

1. *Lymphatic vessels.*—These vessels exist in almost all parts of the body; and have the shape of cylindrical, transparent, membranous tubes, of small size, anastomosing freely with each other, so as to present, everywhere, a reticular arrangement. They are never, according to Professor Müller, so small as the arterial and venous capillaries, and are, almost without exception, visible to the naked eye. G. R. Treviranus asserts, that their walls, like the areolar membrane and other tissues, are made up of minute elementary cylinders, of a diameter of from 0·001 to 0·006 millimètres, placed in a series, side by side and end to end, so as to constitute tubes which form networks, and open into larger lymphatic trunks. They are extremely numerous; more so, however, in some parts than others. They have not been found in the brain, spinal marrow, eye, or internal ear, bones, cartilages, or any non-vascular parts; but this is not a positive proof, that they do not exist in some of them. It may be, that they are so minute as to escape observation. In their progress towards the venous system, they go on forming fewer and fewer trunks; yet always remain small. This uniformity in size is peculiar to them. When an artery sends off a

Fig. 256.



Vessels and Lymphatic Glands of Axilla.

1. The axillary artery. 2. Axillary vein. 3. Brachial artery. 4. Brachial vein. 5. Primitive carotid artery. 6. Internal jugular vein. 7. Subcutaneous lymphatics of arm at its upper part. 8. Two or three of the most inferior and superficial glands into which the superficial lymphatics empty. 9. Deep-seated lymphatics which accompany brachial artery. 10. Lymphatics and glands which accompany infra-scapular bloodvessels. 11. Glands and lymphatics accompanying thoracica longa artery. 12. Deeper-seated lymphatics. 13. Axillary chain of glands. 14. Acromial branches of lymphatics. 15. Jugular lymphatics and glands. 16, 17. Lymphatics which empty into subclavian vein near its junction with right internal jugular vein.

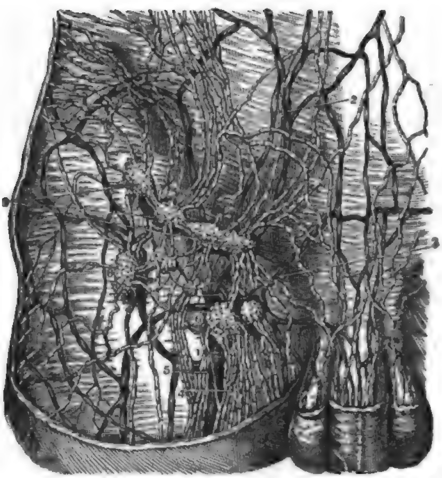
branch, its size is sensibly diminished; and when a vein receives a branch, it is enlarged; but when a lymphatic ramifies, there is generally little change of size, whether the branch given off be large or small.

The lymphatics consist of two planes,—the one *superficial*, the other *deep-seated*. The former creep under the outer covering of the organ, or of the skin, and accompany the subcutaneous veins. The latter are seated more deeply in the interstices of the muscles, or even in the tissue of parts; and accompany the nerves and great vessels. These planes anastomose with each other.

This arrangement occurs not only in the limbs, but the trunk, and in every viscus. In the trunk, the superficial plane is seated beneath the skin; and the deep-seated between the muscles and the serous membrane that lines the splanchnic cavities. In the viscera, one plane occupies the surface; the other appears to arise from the parenchyma.

The two great trunks of the lymphatic system, in which the lymphatic vessels of the various parts of the body terminate, are the thoracic duct, and the great lymphatic trunk of the right side. The course of the thoracic duct has been described already. It is formed of three great vessels;—one, in which all the lymphatics and lacteals of the intestines terminate; and the other two, formed by the union of the lymphatics of the lower half of the body. Occasionally, the duct consists of several trunks, which unite into one before reaching the subclavian vein; but more frequently it is double. In addition to the lymphatics of the lower half of the body, the thoracic duct receives a great part of those of the thorax, and all those from the left half of the upper part of the body. At its termination in the subclavian, there is a valve so disposed as to allow the lymph to pass into the blood; and to prevent the reflux of the blood into the duct. We shall see, however, that its mode of termination in the venous system possesses other advantages. The great lymphatic trunk of the right side is formed by the absorbents from that side of the head and neck, and from the right arm. It is very short, being little more than an inch, and sometimes not a quarter of an inch, in length,—but of a diameter nearly as great as the thoracic duct. A valve also exists at the mouth of

Fig. 257.



Lymphatic Vessels and Glands of the Groin of the Right Side.

1. Saphena magna vein. 2. Veins on the surface of abdomen. 3. External pudic vein. 4. Lymphatic vessels collected in fasciculi and accompanying the saphena vein on its inner side. 5. External trunks of the same set of vessels. 6. Lymphatic gland which receives all these vessels. It is placed on the termination of the saphena vein. 7. Efferent trunks from this gland; they become deep-seated and accompany the femoral artery. 8. One of the more external lymphatic glands of the groin. 9. A chain of four or five inguinal glands, which receive the lymphatics from the genitals, abdomen, and external portion of the thigh.

this trunk, which has a similar arrangement and office with that of the left side.

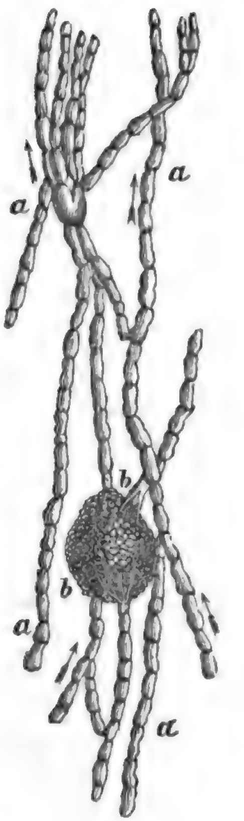
The lymphatics have been asserted to be more numerous than the veins; by some, indeed, the proportion has been estimated at fourteen superficial lymphatics to one superficial vein; whence it has been deduced, that the capacity of the lymphatic is greater than that of the venous system. This must be mere matter of conjecture. The same may be said of the speculations that have been indulged regarding the mode in which the lymphatic radicles arise,—whether by open mouths or by some spongy mediate body. The remarks made regarding the chylous radicles apply with equal force to the lymphatic.

It has been a matter of some interest to determine, whether the lymphatic vessels have other communications with the venous system than by the two trunks just described; or, whether, soon after their origin, they do not open into the neighbouring veins,—an opinion held by many of those, who believe in the doctrine of absorption by the lymphatics exclusively, to explain why absorbed matters are found in the veins. Several of the older, as well as more modern, anatomists, have professed this opinion; whilst it has been strenuously combated by Sömmering, Rudolphi,[1] and others. Vieussens affirmed, that, by means of injections, lymphatic vessels were distinctly seen originating from the minute arteries, and terminating in small veins. Sir William Blizard[2] asserts, that he twice observed lymphatics terminating directly in the iliac veins. Mr. Bracy Clarke[3] found that the trunk of the lymphatic system of the horse had several openings into the lumbar veins. M. Ribes,[4] by injecting the supra-hepatic veins, saw the substance of the injection enter the superficial lymphatics of the liver. M. Alard[5] considers that the lymphatic and venous systems communicate at their origins. Vincent Fohmann[6] thinks, that the lymphatic vessels communicate directly with the veins, not only in the capillaries, but in the interior of the lymphatic glands. Lauth,[7] of Strasburg,—who went to Heidelberg to learn from Fohmann his plan of injecting,—announced the same facts in 1824. By this anatomical arrangement, Lauth explains how an injection, sent into the arteries, reaches the lymphatics, without being effused into the areolar tissue; the injection passing from the arteries into the veins, and thence, by a retrograde route, into the lymphatics. M. Béclard believed, that this communication exists at least in the interior of the lymphatic glands; and he supported his opinion by the fact, that in birds, in which these glands are wanting, and are replaced by plexuses, the lymphatic vessels in the plexuses are distinctly seen opening into the veins. Lippi[8] has made these communications the

[1] Grundriss der Physiologie, u. s. w., 2ter Band, 2te Abtheilung, s. 247, Berlin, 1828.
[2] Physiological Observations on the Absorbent System of Vessels, Lond., 1787.
[3] Rees's Cyclopedia, art. Anatomy, Veterinary. [4] Magendie, Précis, etc., ii. 238.
[5] Du Siége et de la Nature des Maladies, ou nouvelles considérations touchant la véritable action du Système Absorbant, etc., Paris, 1821.
[6] Ueber die Verbindung der Saugadern mit den Venen, Heidelb., 1821, und Das Saugadersystem der Wirbelthiere, Heft 1, Heidelb., 1824; and Mém. sur les communications des vaisseaux lymphatiques avec les veines, Liége, 1832.
[7] Essai sur les Vaisseaux Lymphatiques, Strasbourg, 1824.
[8] Illustrazioni Fisiologiche, etc., Firenz., 1825.

subject of an express work. According to him, the most numerous exist between the lymphatic vessels of the abdomen, and the vena cava inferior and its branches. So numerous are they, that every vein receives a lymphatic vessel, and the sum of all would be sufficient to form several thoracic ducts. Opposite the second and third lumbar vertebræ, the lymphatic vessels are manifestly divided into two orders:—some ascending, and emptying themselves into the thoracic duct; others descending and opening into the renal vessels and pelves of the kidneys. Lippi admits the same arrangement, as regards the chyliferous vessels; and he adopts it to explain the promptitude with which drinks are evacuated by the urine.

Fig. 258.



Lymphatics.

a, a, a, a. Afferent and efferent lymphatic vessels proceeding towards thoracic duct. *b, b.* Lymphatic glands. The arrows indicate the direction in which the chyle passes.

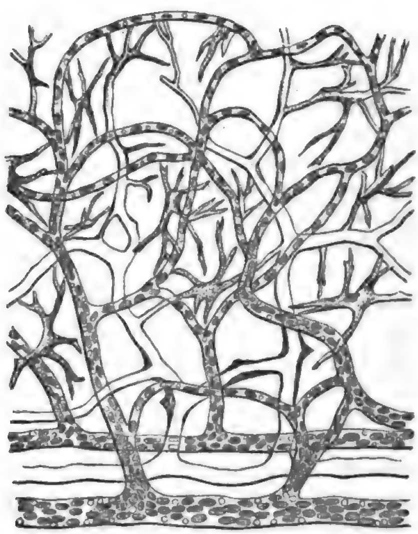
Subsequent researches have not, in general, confirmed the statements of Lippi. G. Rossi,[1] indeed, maintains, that the vessels, which Lippi took for lymphatics, were veins. It would appear, however, that when Rossi was in Paris, he was unable to demonstrate, when requested to do so by M. Breschet, the very things, that he had previously figured and described. Panizza, too, affirms, that no direct union or continuity between the venous capillaries and lymphatics has ever been made manifest to the eye, either in the human subject or the lower animals:[2] and, on the whole, the observations of Lippi as to the alleged termination of lymphatics in various veins of the abdomen have generally been either rejected as erroneous or held to refer to deviations from the normal condition.[3] It is proper to remark, however, that, recently, Dr. A. Nuhn,[4] Prosector at Heidelberg, has maintained, that there is a regular communication between the abdominal lymphatics and veins, and describes three cases of the kind which fell under his own observation. In two of these the lymphatics opened into the renal veins; in the third into the vena cava. The article contains a good history of the views of different observers on the communication between the absorbents and veins.

We are perhaps justified in concluding with Panizza, that anatomy has not hitherto succeeded in determining, with physical certainty, in what relation the sanguiferous and lymphatic systems stand to each other, at their extreme

[1] Omodei's Annali Universali, Jan., 1826.
[2] Osservazioni Antropo-zootomico-fisiologiche, Pavia, 1833; and Breschet's Système Lymphatique, Paris, 1836.
[3] Quain's Human Anatomy, by Quain and Sharpey, Amer. edit., by Dr. Leidy, ii. 43, Philad., 1849.
[4] Müller's Archiv. fur Anatomie, u. s. w., Heft 2, s. 173, Berlin, 1848.

ramifications.[1] M. Magendie[2] conceives the most plausible view regarding the lymphatics to be:—that they arise by extremely fine roots in the substance of the membranes and areolar tissue, and in the parenchyma of organs, where they appear continuous with the final arterial ramifications;—as it frequently happens, that an injection sent into an artery passes into the lymphatics of the part to which it is distributed. By some, they are described as commencing either in closely meshed networks, interspersed among the bloodvessels of the several tissues, or else in pointed closed tubes or processes, as shown in the marginal figure of the lymph and bloodvessels in a part of the tail of the tadpole;—the bloodvessels being denoted by the corpuscles in them. In this state, many of the extremities of the lymphatics appear to communicate with pointed or star-shaped cells; but this, according to Messrs. Kirkes and Paget,[3] may be peculiar to the embryonic state, as no similar cells are seen in the adult; nor is there any appearance of the existence of cells for the elaboration of lymph, similar to those described as existing in the intestinal villi.

Fig. 259.



Bloodvessels and Lymphatics from the Tail of the Tadpole.

The structure of the lymphatic vessels is like that of the lacteals. They have the same number and character of coats; the same crescentic valves or sphincters, occurring in pairs, and giving them the knotted and irregular appearance, for which they are remarkable;—every contraction indicating the presence of a pair of valves, or sphincter. The minutest lymphatics seem, however, to be destitute of valves: but they are discernible in those of less than one-third of a line in diameter, and have the same structure as those of the veins. In man, each lymphatic, before reaching the venous system, passes through a *lymphatic gland* or *ganglion*, formerly called a *conglobate gland*. These organs are extremely numerous; and in shape, structure, and probably in function, resemble entirely the mesenteric glands. They, therefore, do not demand distinct notice. They exist more particularly in the axillæ, neck, neighbourhood of the lower jaw, beneath the skin of the nape of the neck, in the groins, and pelvis in the neighbourhood of the great vessels. The connexion between the lymphatics and those

[1] See, on both sides of this subject, Müller's Handbuch, u. s. w., Baly's translation, p. 273, Lond., 1838; and Weber's Hildebrahdt's Handbuch der Anatomie, iii. 113, Braunschweig, 1831.

[2] Précis, &c., ii. 194.

[3] Manual of Physiology, Amer. edit., p. 205, Philad., 1849.

glands is the same as that between the chyliferous vessels and mesenteric glands.

M. Chaussier includes in the lymphatic system certain organs, whose uses in the economy are not manifest,—the thymus gland, the thyroid, the supra-renal capsules, and perhaps the spleen. These he considers to be varieties of the same species, and terms them all *glandiform ganglions*.

The *thymus gland* is a body consisting of distinct lobes, situate at the upper and anterior part of the thorax behind the sternum. It has been considered to belong more particularly to fœtal existence, and will be investigated hereafter. The *thyroid gland* is, also, a lobated organ, situate at the anterior part of the neck beneath the skin and subcutaneous muscles, and resting on the anterior and inferior part of the larynx, and first rings of the trachea. It is formed of lobes, which subdivide into lobules and granula; is of a red, and at times yellow colour; and presents, internally, cells or vesicles, filled with a viscid and colourless or yellowish fluid. Collected on the point of a knife after incising the gland, it appears like weak solution of gum, and is almost devoid of the ropiness of white of egg. Put into common rectified spirit it seems to lose only a little water; becomes solid, but not opaque; and loses but little. The same effects result in the cells when the gland is boiled for a quarter of an hour: no apparent solution occurs. The thyroid gland has no excretory duct; and, consequently, it is difficult to imagine its use. It is larger in the fœtus than in the adult, and has been supposed to be, in some way, inservient to fœtal existence. It continues, however, through life; receives large arteries, as well as a number of nerves and lymphatics, and hence, it has been supposed, fills some important office through the whole of existence. This, however, is conjectural. Mr. King[1] has affirmed, what had been already imagined by many, that the absorbent vessels of the thyroid convey its peculiar secretion to the great veins of the body. It is the seat of *goître* or *bronchocele*, the *swelled neck*, *Derbyshire neck*, *papas*, &c., as it has been termed in different quarters of the globe,—a singular affection, which is common at the base of lofty mountains in all parts of the world; and for the cure of which, we have a valuable remedy in iodine. The eutrophic agency of this drug is particularly exerted on the thyroid, and it affords an additional instance, to the many already known, of remedial agents exerting their properties upon a particular organ, without our being able, in the slightest degree, to account for the preference. Iodine stimulates, perhaps, the absorbent vessels of the gland to augmented action; it certainly modifies the nutrition of the organ; and the consequence is absorption of the morbid deposit. Lastly; the *supra-renal* or *atrabiliary capsules* or *glands* are small bodies in the abdomen, behind the peritoneum, and above each kidney, which are larger in the fœtus than in the adult. The arteries distributed to them are of considerable size. These bodies consist of small sacs, with thick parenchymatous parietes; are lobular and granular,—the internal cavity being filled, according to Sir Everard Home,[2] with a viscid fluid

[1] Guy's Hospital Reports, i. 437, Lond., 1836, and Sir Astley Cooper, ibid., p. 448.
[2] Lect. on Comp. Anat., v. 262, Lond., 1828.

pulp or oil, which is reddish in the fœtus, yellow in childhood, and brown in old age. Under the microscope, the pulp is found to consist of minute oil-like spheroids, of very unequal size, varying from $\frac{1}{24000}$th to $\frac{1}{8000}$th of an inch in diameter.[1] They continue during life: but with their uses we are unacquainted. By the ancients, they were believed to be the secretory organs of the imaginary atrabilis; hence their name. Sir Everard Home considers that they act like a filter, "by which any oil left in the arterial branches that are near the kidneys may be separated and prevented from making its escape by the tubæ uriniferæ of these glands." Dr. Carpenter[2] thinks the only function that can be assigned them with anything like probability is that of serving as a means of conveying into the veins the blood sent through the renal artery, when, from any cause, the secreting function of the kidneys is partly or wholly checked, and their capillary circulation stagnates in consequence.

All these bodies are probably concerned in lymphosis; but at the same time—as shown hereafter,—they may act under special circumstances as diverticula to the blood and hence merit the name—now generally assigned to them—of *vascular glands*.

2. LYMPH.

Lymph may be procured in two ways, either by opening a lymphatic vessel, and collecting the fluid that issues from it,—but this is an uncertain method,—or by making an animal fast four or five days, and obtaining the fluid from the thoracic duct. This has been considered pure lymph; but it must be mixed with the product of the digestion of the different secretions from the portion of the digestive tube above the origin of the chyliferous vessels. Chyle itself is nothing more than lymph of the intestines, containing matter absorbed from the digested food; and in the intervals of digestion lymph alone is found in the chyliferous vessels.

The fluid, obtained as above-mentioned, is of a rosy, slightly opaline tint; a markedly spermatic odour, and saline taste. At times, it is of a decidedly yellowish colour; at others, of a madder red; circumstances which may have given occasion to erroneous inferences from experiments made on the absorption of colouring matters. Its specific gravity has been found, by some, to be 1022·28: by others, 1·037. Its colour is affirmed to be more rosy in proportion to the length of time the animal has fasted. When examined by the microscope, it exhibits globules or corpuscles like those of the chyle; and, like the chyle, bears considerable analogy, in its chemical composition, to the blood. Both may, indeed, without impropriety, be regarded as rudimental blood.

Bodies similar to these *lymph corpuscles* are seen mingled with the blood, occupying generally the space between the main current and the parietes of the vessel. Some, however, regard them as blood corpuscles in process of solution or disintegration; and M. Mandl[3] thinks they do not exist in the fluid during life, but are owing to the coagulation of

[1] Gulliver, in Gerber's General Anatomy, p. 103.
[2] Principles of Human Physiology, § 710, Lond., 1842.
[3] Anatom. Microscop., i. 15.

its fibrin. More recently, he has stated, that from experiments made with M. Breschet, it was evidently impracticable to procure pure lymph by opening the lymphatic hearts of frogs. Blood globules always existed in it; and this, he thinks, throws doubts on the view, that lymph corpuscles are transformed into blood corpuscles.

When left at rest, lymph separates into two portions;—the one a liquid, nearly like the serum of the blood; the other a coagulum or clot of a deeper rosy hue; in which is a multitude of reddish filaments, disposed in an arborescent manner; and, in appearance, very analogous to the vessels distributed in the tissue of organs. When a portion of coagulated lymph is examined, it seems to consist of two parts:—the one solid, formed of numerous cells, which contains the other or more liquid part; and if the former be separated, the latter coagulates. Mr. Brande[1] collected the lymph from the thoracic duct of an animal, that had been kept without food for twenty-four hours. He found its chief constituent to be water, besides which, it contained chloride of sodium and albumen:—the latter being in such minute quantity, that it coagulated only by the action of galvanism. The lymph of a dog yielded to M. Chevreul, water, 926·4; fibrin, 4·2; albumen, 61·0; chloride of sodium, 6·1; carbonate of soda, 1·8; phosphate of lime, phosphate of magnesia, and carbonate of lime, 0·5. That of the horse yielded to M. Lassaigne, water, 192·5; fibrin, 0·33; albumen, 5·73; chlorides of sodium and potassium, with soda and phosphate of lime, 1·43. Total, 100. MM. Marchand and Colberg[2] found its constituents to be,—water, 96·926; fibrin, 0·520; albumen, 0·434; osmazome (and loss), 0·312; fatty oil and crystalline fat, 0·264; chloride of sodium, chloride of potassium, carbonate and lactate of an alkali, and sulphate of lime, phosphate of lime, and oxide of iron, 1·544. Total, 100·000. Gmelin found, in 1000 parts of human lymph, water, 961·0; solid constituents, 30·74; fibrin, 5·20; albumen, 4·34; extractive matter, 3·12; fluid and crystalline fat, 2·64; chlorides of sodium and potassium, alkaline sulphates and carbonates, sulphate and phosphate of lime, and peroxide of iron, 15·44. M. L'Héritier[3] analyzed the lymph obtained from the thoracic duct of a man who died from softening of the brain, and took nothing but a little water for thirty hours preceding his death. It contained in 1000 parts,—water, 924·36; solid constituents, 75·64; fibrin, 3·20; fat, 5·10; albumen, 60·02; salts, 8·25. Lymph, collected from the absorbent vessels of the neck of a horse was elaborately analyzed by Nasse, and found to contain in 1000 parts,—water, 950; solid residue, 50; albumen with fibrin, 39·111; water extract, 3·248; spirit extract, 0·877; alcohol extract, 0·755; ethereal extract, 0·088; oleate of soda, 0·575; carbonate of soda, 0·560; phosphate of soda, 0·120; sulphate of potassa, 0·233; chloride of sodium, 4·123; carbonate of lime, 0·104; phosphate of lime with some iron, 0·095; carbonate of magnesia, 0·044; silica, 0·067. He compared the lymph with the serum from the blood of a healthy horse; and found a remarkable coincidence in the salts of the two fluids.

[1] Turner's Chemistry, 4th Amer. edit., p. 567.

[2] Müller's Archiv. Jahrgang, 1838, s. 129, cited in V. Bruns, Lehrbuch der Physiologie des Menschen, s. 135, Braunschweig, 1841.

[3] Traité de Chimie Pathologique, p. 18, Paris, 1842.

	Serum.	Lymph.
Alkaline chlorides	4·055	4·123
Alkaline carbonates (oleate of soda included)	1·130	1·135
Alkaline sulphates	0·311	0·233
Alkaline phosphates	0·115	0·120
	5·611	5·611[1]

The same observer[2] has given a tabular view of six analyses of the lymph of the horse and ass.

	Reuss and Emmert.	Gmelin. I.	Gmelin. II.	Lassaigne.	Rees.	Nasse.
Water	960·0	961·0	967·70	925·00	965·36	950·00
Fibrin nearly	3·0	2·5	1·30	3·30	1·20	39·11
Albumen		27·5	14·85		12·00	
Extractive matter soluble only in water		2·1	2·58	57·36	13·19	3·25
Extractive matter soluble in alcohol	39 6	6·9	9·69		2·40	1·63
Fat		0·0	traces		a trace	0·09
Soluble salts } contained in the extractive matters						
Salts of lime, magnesia and silica } contained in the extractive matters				14·34	5·85	5·61
Oxide of iron					a trace	0·31
Loss	0·4		3·88			

A comparative analysis of the chyle and lymph of the ass has been made by Dr. G. O. Rees.[3] The fluids were obtained from the chyliferous and lymphatic vessels seven hours after a full meal, previous to their entrance into the thoracic duct.

	Chyle.	Lymph.
Water	90·237	96·536
Albuminous matter	3·516	1·200
Fibrinous matter	0·370	0·120
Animal extractive matter, soluble in water and alcohol	0·332	0·240
Animal extractive matter, soluble in water only	1·233	1·319
Fatty matter	3·601	a trace.
Salts:—alkaline chloride, sulphate, and carbonate, with traces of alkaline phosphate and oxide of iron	0·711	0·585
	100·000	100·000

The chyle—it will be observed—contains a larger proportion of decidedly organizable matters. Dr. Rees[4] examined the contents of the thoracic duct of a human subject, procured an hour and a quarter after death by hanging. They amounted to six drachms, and yielded the following results:—

Water	90·48
Albumen, with traces of fibrinous matter	7·08
Aqueous extractive (zomodine)	0·56
Alcoholic extractive (osmazome)	0·52
Alkaline chloride, carbonate, and sulphate, with traces of phosphate, and oxide of iron	0·44
Fatty matters	0·92
	100·00

[1] Simon's Animal Chemistry, Sydenham Soc. edit., p. 353, Lond., 1845, or Amer. edit., Philad., 1846.
[2] Wagner's Handwörterbuch der Physiologie, 9te Lieferung, s. 396, Braunschweig, 1845.
[3] Lond. Med. Gazette, Jan., 1841.
[4] Proceedings of the Royal Society, Feb. 10, 1842.

Chyle and lymph strikingly therefore resemble each other; and according to M. Millon,[1] when taken from the same animal at one time the analogy in composition is very great. Without impropriety they may, indeed, be termed rudimental blood.

It is impossible to estimate the quantity of lymph contained in the body. It would seem, that notwithstanding the great capacity of the lymphatic vessels, there is, under ordinary circumstances, little fluid circulating in them. Frequently, when examined, they have appeared to be empty, or pervaded by a mere thread of lymph. M. Magendie[2] endeavoured to obtain the whole of the lymph from a dog of large stature. He could collect but an ounce and a half; and it appeared to him that the quantity increased whenever the animal was kept fasting; but on this point he does not seem to express himself positively.

3. PHYSIOLOGY OF LYMPHOSIS.

The term *lymphosis* has been proposed by Chaussier for the action of elaboration by which lymph is formed,—as *chylosis* has been used for the formation of chyle, and *hæmatosis* for that of the blood. In describing the organs concerned, the striking similarity—we might almost say—identity in structure and arrangement between them and the chyliferous organs will have been apparent. A part of the vascular apparatus is common to both; and they manifestly constitute one and the same system. This would be sufficient to induce us to assign them similar functions; and it would require powerful and positive testimony to establish an opposite view. At one period, lymph was considered to be simply the watery portion of the blood; and the lymphatic vessels were regarded as the continuation of ultimate arterial ramifications. It was affirmed, that the blood, on reaching the terminal branches of the arteries, separated into two parts; the red and thicker portion returning to the heart by the veins; and the white, serous portion —*liquor sanguinis*—by the lymphatics.[3] The reasons for this belief were, the great resemblance between lymph and the serum of the blood; and the facility with which an injection passes, in the dead body, from the arterial into the lymphatic capillary vessels. M. Magendie has revived the ancient doctrine; and, of consequence, no longer considers the lymphatics to form part of the absorbent system; but to belong to the circulatory apparatus, and to serve the office of waste pipes, in case of emergency. Without canvassing this subject now, we may assume it for granted, that the lymph which circulates in the lymphatic vessels is as identical in its nature, or as little subject to alteration, as the chyle; and that, consequently, whatever may be the materials that constitute it, an action of elaboration and selection must be exerted in its formation.

It has been conceived, that many of the tissues of the body, the serous membranes, for example, do not receive red blood; and must, consequently, be nourished by white blood. The lymphatics, in such cases, have been considered to be to the white arteries what the veins

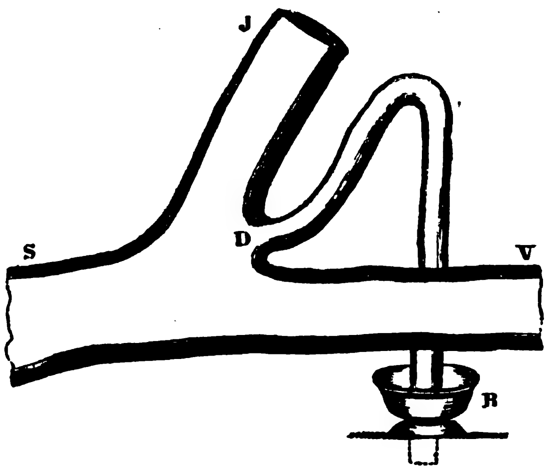
[1] Archives Générales de Médecine, Févr., 1850, p. 237.
[2] Op. citat., ii. 192.
[3] Kirkes and Paget, Manual of Physiology, Amer. edit., p. 256, Philad., 1849.

are to the red. Such has been presumed to be one of their offices, but it will be seen, hereafter, that all the tissues supplied with vessels receive red blood; and hence it is unnecessary to suppose, that the lymphatics execute any venous function.

Assuming, for the present, that lymph is wholly obtained from materials already deposited in the body; the next inquiry is,—the mode in which its formation and simultaneous absorption are effected. On this topic, we have no arguments to employ in addition to those adduced regarding the function of the chyliferous radicles. In every respect, they are situate identically, and to the history of the latter we must refer for an exposition of the little we know of this part of lymphosis.

The causes of the progression of the lymph in the vessels are the same as those that influence the chyle. In addition, however, to those mentioned under *chyliferous absorption*, there is one that applies equally to the chyliferous and lymphatic vessels: this is the mode in which the thoracic duct enters the subclavian vein. It has been already observed that it occurs at the point of junction between the jugular and subclavian, as at D, Fig. 260, where J represents the jugular, and V S the subclavian, in which the blood flows from V towards S, the cardiac extremity.

Fig. 260.



Termination of Thoracic Duct.

Now, it is a physical fact, that when a small tube is inserted perpendicularly into the lower side of a horizontal conical pipe, in which water is flowing from the narrower to the wider portion; and if the small vertical tube be made to dip into a vessel of water, not only will the water of the larger pipe not descend into the vessel; but it will draw up the water through the small tube so as to empty the vessel.[1] Instead of supposing the canals in Fig. 260, to be veins and the thoracic duct; let us presume that they are rigid mechanical tubes; and that the extremity of the tube D, which represents the thoracic duct, dips into the vessel B. As the fluid, proceeding from J to S and V to S, is passing from the narrower portions of conical tubes to wider, it follows, that the fluid will be drawn out of the vessel B, simply by traction, or, by what Venturi[2] terms the *lateral communication of fluids*. This would happen in whatever part of the vessel the tube B D termi-

[1] Sir C. Bell, in Animal Mechanics, p. 41, Library of Useful Knowledge, Lond., 1829.
[2] Sur la Communication Latérale du Mouvement dans les Fluides, Paris, 1798.

nated. But its insertion at D has another advantage. By the mode in which the current from J towards S unites with that from V towards S, a certain degree of diminished pressure must exist at D; so that the atmospheric pressure, on the surface of the water in the vessel B, will be exerted in propelling it forwards. In the progress, then, of the chyle and lymph along the thoracic duct, not only may the traction of the more forcible stream along the veins draw the fluid in the thoracic duct along with it, but, owing to the diminished pressure at the mouth of the duct, atmospheric pressure may have some—although probably but little—influence, in forcing the chyle and lymph from the chyliferous and lymphatic radicles onwards. The lymphatic glands have been looked upon as small hearts for the propulsion of lymph; and Malpighi accounts for the greater number in the groin in this way;—the lymph having to ascend to the thoracic duct against gravity: and this appears to have been somewhat the opinion of Bichat. There seems, however, to be nothing in their structure that ought to lead to this belief; and, if it be not muscular or contractile, it is manifest, that their number must have the effect of retarding rather than accelerating the flow. The most prevalent sentiment is, that they are somehow concerned in the admixture of the lymph; and by many it is conceived, that some kind of elaboration is effected by them; but, on this topic, we have only conjectures. Of their true functions we know nothing definite.

On the subject of the moving powers of the lymph, M. Adelon[1] has remarked, that if we admit it to be the serous portion of the blood; and that the lymphatics are vessels of return, as the veins are, the heart might be considered to have the same influence over lymphatic, that it has been presumed to have over venous, circulation; and whether we admit this or not, as the thoracic duct opens into the subclavian vein, the influence of the suction power of the organ on the venous blood may affect the progression of the chyle also. It cannot, however, as Müller[2] remarks, be the primary cause of the motion of the chyle, for Autenrieth, Tiedemann, and Carus observed, when a ligature was applied to the thoracic duct, that the part of the duct below the ligature became distended even to bursting. We shall see hereafter, that during inspiration, absorption, it is imagined, may be facilitated by the dilatation of the chest, and the necessary diminution of pressure on the heart and great vessels.

Professor Müller[3] discovered, that the frog, and several other amphibious animals, are provided with large receptacles for lymph, situate immediately under the skin, and, like the heart, exhibiting distinct and regular pulsations. The use of these lymph hearts appears to be to propel the lymph along the lymphatics. In the frog, four of them have been found; two posterior, behind the joint of the hip; and two anterior, on each side of the transverse process of the third vertebra, and under the posterior extremity of the scapula. The pulsations of

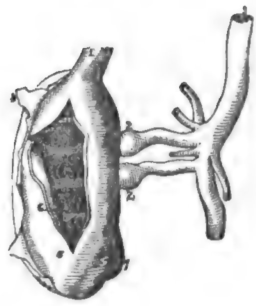
[1] Art. Absorption, in Dict. de Médecine, 2de édit., i. 239, Paris, 1832; and Physiologie de l'Homme, edit. cit., iii. 92.

[2] Handbuch, u. s. w.; and Baly's translation, p. 284, Lond., 1838.

[3] Philos. Transact. for 1833; and op. cit. See, also, his Observations on the Lymphatic Hearts of Tortoises, in Müller's Archiv., Heft 1, 1840.

these lymphatic hearts do not correspond with those of the sanguiferous heart; nor do those of the right and left sides occur synchronously. They often alternate irregularly. Prof. E. H. Weber has described them in a larger species of serpent—*python bivittatus*;[1] and Dr. Joseph J. Allison, of Philadelphia,[2] a young and zealous observer, who was cut off early in his career, saw them in the tadpole, the frog, the sauria, ophidia, and chelonia. His researches led him to conclude:—*First*. That the pulsations of the lymphatic organs vary in different specimens (frogs and tadpoles) from 60 or less to 200 per minute. *Secondly*. That they vary in the same individual so as sometimes to become double in frequency. *Thirdly*. That the lymphatic pulsations bear no fixed relation to those of the pulmonary heart or to respiration, the lymphatic hearts beating—on an average—with greater frequency.

Fig. 261.



Lymph Heart of Python Bivittatus, after Weber. Heart 9 lines long; 4 broad.

4. External areolar coat. 5. Thick muscular coat; four muscular columns cross the cavity, which communicates with three lymphatics—only one, 1, seen here, and two veins, 2, 2. 6. Smooth lining membrane of the cavity. 7. An appendix or auricle, the cavity of which communicates with the other.

More recently, Professor Stannius[3] has discovered lymphatic hearts in various birds.

Unlike that of the heart, the action of these lymph hearts appears to be dependent upon a certain limited portion of the spinal cord; for Volkmann[4] found, that by dividing the anterior or motor roots of the spinal nerves connected with them, the pulsations immediately ceased.

The course of the lymph is by no means rapid. If a lymphatic be divided on a living individual, the lymph oozes slowly, and never with a jet. M. Cruikshank estimated its velocity along the vessels to be four inches per second or twenty feet per minute; but it is probably much less. M. Collard de Martigny[5] obtained nine grains of lymph in ten minutes from the thoracic duct of a rabbit, which had taken no food for twenty-four hours. Having pressed out the lymph from the principal lymphatic trunk of the neck, in a dog, the vessel filled again in seven minutes: in a second experiment it filled in eight minutes. The data for any correct evaluation of this matter are altogether inadequate, the deranging influence of all such experiments being considerable.

In man and living animals, the lymphatics of the limbs, head, and neck rarely contain lymph; their inner surface appearing to be merely lubricated by a very thin fluid. Occasionally, however, the lymph stops in different parts of the vessels; distends them; and gives them an appearance very like that of varicose veins, except as to colour. Sömmering states, that he saw several in this condition on the top of

[1] Müller, op. citat., p. 275.

[2] American Journal of the Medical Sciences, for August, 1838.

[3] Müller's Archiv., 1843, Heft 5.

[4] Ibid., 419, Berlin, 1844; and Valentin, Lehrbuch der Physiologie des Menschen, ii. 769, Braunschweig, 1844.

[5] Journal de Physiologie, tom. viii.

the foot of a female; and M. Magendie one around the corona glandis of a male. In dogs, cats, and other living animals, lymphatics, filled with lymph, are frequently seen at the surface of the liver, gall-bladder, vena cava, vena portæ, and at the sides of the spine. Magendie remarks, that he has never met with the thoracic duct empty, even when the lymphatics of the rest of the body were entirely so.[1] It must be recollected, however, that the thoracic duct must always contain the product of the digestion either of food or of secretions from the alimentary tube. The stagnation of lymph in particular vessels has given occasion to the belief, that it flows with different degrees of velocity in different parts of the system; and this notion has entered into the pathological views of writers, who have presumed, that something like determinations of lymph may occur, and produce lymphatic swellings. M. Bordeu,[2] indeed, speaks of *currents* of lymph. All the phenomena of the course of the lymph negative, however, this presumption; and induce us to believe, that its progress is pretty uniform, and always slow; and when an accumulation, or engorgement, or stagnation occurs in any vessel, it is more probably owing to increased formation by the lymphatic radicles that communicate with the vessel in question, or to loss of tone in the parietes of the engorged lymphatics.

The lymph, which proceeds by the thoracic duct, is emptied, along with the chyle, into the subclavian vein. At the confluence, a valve is placed, which does not, however, appear to be essential, as the duct opens so favourably between the two currents from the jugular and subclavian, that there is little or no tendency in the blood to reflow into it. It has been suggested, that its use may be, to moderate the instillation of the fluid from the thoracic duct into the venous blood.

With regard to the question, whether the lymph is the same at the radicles of the lymphatics as in the thoracic duct, or whether it does not gradually become more and more animalized in its course towards the venous system, and especially in its progress through the lymphatic glands, the remarks made upon this subject, as respects the chyle, apply with equal force to the lymph. Our ignorance is no less profound.

The glands of the mesentery, and lymphatics in general, seem to be concerned in some of the most serious diseases. Swelling of the lymphatic glands of the groin may indicate the existence of a venereal sore on the penis. A wound on the foot produces tumefaction of the inguinal glands; one on the hand inflames those of the axilla. Whenever, indeed, a lymphatic gland is symptomatically enlarged, the source of irritation will be found at a greater distance from the vein into which the great lymphatic trunks pour their fluid than the gland is. In plague, one of the essential phenomena is swelling of the lymphatic glands of the groin and axilla; hence, it has been termed *adeno-adynamic fever* (from αδην, a gland). In scrofula, the lymphatic system is generally deranged; and, in the doctrine of Broussais, a very active sympathy is affirmed to exist between the glands of the mesentery, and the mucous surface of the stomach and intestines. This discovery, we are told, belongs to the "*physiological doctrine*," which has shown, that

[1] Précis, &c., ii. 224.

[2] Œuvres complètes, par Richerand, Paris, 1818.

all gastro-enterites are accompanied by tumefaction of the mesenteric glands: although chyle may be loaded with acrid, irritating, or even poisonous matters, it traverses the glands with impunity, provided it does not inflame the gastro-enteric mucous surface. "Our attention," Broussais[1] adds, "has been for a long time directed to this question, and we have not observed any instance of mesenteric ganglionitis, which had not been preceded by well-evidenced gastro-enteritis." The discovery will not immortalize the "doctrine." We should as naturally look for tumefaction of the mesenteric glands or ganglia, in cases of irritation of the intestine, as for enlargement of the glands of the groin in irritation of the foot.

Lastly; the lymph, from whatever source obtained—united with the chyle—is discharged into the venous system. Both, therefore, go to the composition of the body. They are entirely analogous in properties; but differ materially in quantity;—the nutritious fluid, formed from materials obtained from without, being far more copious. A due supply of it is required for continued existence; yet the body can live for a time, when the supply of nutriment is entirely cut off. Under such circumstances, the necessary proportion of nutritive fluid must be obtained from the decomposition of the tissues; but, from the perpetual drain, that takes place through the various excretions, this soon becomes insufficient, and death is the result. In a note to the recent editions of his "Principles of Human Physiology,"[2] Dr. Carpenter remarks, that at the time of the publication of the first edition of his work (1842) he was under the impression, that the view maintained by him, "that the special function of the lymphatics like that of the lacteals is *nutritive* absorption," was altogether novel. The author attaches little value to originality in such matters; but he thinks it well to state, that the doctrine in the text is, that adopted by him in the first edition of this work (1832), and taught by him ever since he has been a teacher; yet he is far from regarding it as original with him.

We have seen, then, that both chyle and lymph are poured into the venous blood;—itself a compound of the residue of arterial blood, and various heterogeneous absorptions. As an additional preliminary to the investigation of the agents of internal absorption, let us inquire into the nature and course of the fluid contained in the veins; but so far only as to enable us to understand the function of absorption; the other considerations relating to the blood appertain to the function of circulation.

III. VENOUS ABSORPTION.

The apparatus of venous absorption consists of myriads of vessels called *veins*, which commence in the very tissues, by what are called *capillary vessels*, and thence pass to the great central organ of the circulation—the *heart;* receiving, in their course, the products of the various absorptions effected not only by themselves, but by the chyliferous

[1] Traité de Physiologie, &c., and Bell and La Roche's translation, 3d Amer. edit., p. 362, Philadelphia, 1832.

[2] Fourth American edition, p. 506, Philad., 1850. See on this subject, Adelon, Art. Absorption, in Dict. de Médecine, i. p. 117, Paris, 1821; and Moultrie, American Journal of the Medical Sciences for 1827, and On the Organic Functions of Animals, Charleston, 1844.

and lymphatic vessels. The anatomy of the venous system will be given under Circulation.

1. PHYSIOLOGY OF VENOUS ABSORPTION.

Whilst the opinion prevailed universally, that the lymphatics are the sole agents of absorption, the fluid, circulating in the veins, was considered to consist entirely of the residue of arterial blood, after it had passed through the capillary system, and been subjected to the different nutritive processes. We have seen, however, that drinks are absorbed by the mesenteric veins; and we shall hereafter find, that various other substances enter the venous system. It is obvious, therefore, that venous blood cannot be simply the residue of arterial blood; and we can thus account for the greater capacity of the venous than of the arterial system. The facts, which were referred to, when considering the absorption of fluids from the intestinal canal, may have been sufficient to show, that veins are capable of absorbing; as odorous and colouring properties of substances were distinctly found in the mesenteric veins. A question arises, whether any vital elaboration is concerned, as in the case of the chyle, or whether the fluid, when it attains the interior of the vessel, is the same as without? M. Adelon,[1]—who, with many of the German physiologists, believes in both venous and lymphatic absorption, and venous and chyliferous absorption,—conceives, that a vital action takes place at the very extremities of the venous radicles, precisely similar to that which is presumed to be exerted at the extremities of the lymphatic and chyliferous radicles. In his view, consequently, an action of elaboration is exerted upon the fluid, which becomes, in all cases, converted into venous blood at the very moment of absorption. On the other hand, MM. Magendie,[2] Fodéra,[3] and others maintain, that the substance when possessed of the necessary tenuity soaks through the vessel; and that this act of imbibition is purely physical. In their view, consequently, the fluid within the vessel must be the same as without.

In favour of the vital action of the veins we have none of that evidence, which strikes us in the case of the chyliferous and lymphatic vessels. In the last we invariably find fluids, identical—in all essential respects—in physical characters; and never containing extraneous matter,—if we make abstraction of certain salts, that have been occasionally met with in the thoracic duct. In the veins, on the other hand, the sensible properties of odorous and colouring substances have been frequently apparent. It may be remarked, however, that the fluid, flowing in the veins, is as identical in composition as the chyle or the lymph. This is true; but it must be recollected, that the greater part of it is the residue of arterial blood; and that its hue and other sensible properties are such as to disguise any absorbed fluid, not itself possessing strong characteristics. The fact,—now indisputable,—that various substances, placed outside the veins, have been detected in the blood within, is not only a proof that the veins absorb; but that no

[1] Art. Absorption, in Dict. de Médecine, 2de édit., i. 239, Paris, 1832; and Physiologie de l'Homme, 2de édit., iii. 113, Paris, 1829.

[2] Précis, &c., 2de édit., ii. 271.

[3] Recherches Expérimentales sur l'Exhalation et l'Absorption, Paris, 1823.

action of elaboration is exerted on the absorbed fluid. Of this we have the most convincing proof in certain experiments by M. Magendie.[1] In exhibiting to his class the mode in which medicines act upon the system, he showed, on a living animal, the effects of introducing a quantity of water, of the temperature of 104° Fah., into the veins. In performing this experiment, it occurred to him to notice what would be the effect produced by artificial plethora on the phenomena of absorption. Having injected nearly a quart of water into the veins of a dog of middle size, he placed in the cavity of the pleura a small dose of a substance with the effects of which he was familiar, and was struck with the fact, that they did not exhibit themselves for several minutes after the ordinary period. He immediately repeated the experiment, and with a like result. In several other experiments, the effects appeared at the ordinary time, but were manifestly feebler than they ought to have been from the dose of the substance employed; and were kept up much longer than usual.

In another experiment, having introduced as much water as the animal could bear without perishing,—which was about two quarts,—the effects did not occur at all. After having waited nearly half an hour for their developement, which generally required only about two minutes, he inferred, that if the distension of the bloodvessels was the cause of the defect of absorption, if the distension were removed, absorption ought to take place. He immediately bled the animal largely in the jugular; and, to his great satisfaction, found the effects manifesting themselves as the blood flowed. He next tried whether, if the quantity of blood were diminished at the commencement of the experiment, absorption would be more rapid; and the result was as he anticipated. An animal was bled to the extent of about half a pound; and the effects, which did not ordinarily occur until after the second minute, appeared before the thirtieth second. As the results of these experiments seemed to show, that absorption is in an inverse ratio to the degree of vascular distension, he inferred, that it is effected physically; is dependent upon capillary attraction; and ought to take place as well after death as during life. To prove this, he instituted the following experiments.—He took a portion of the external jugular of a dog, about an inch long and devoid of branches. Removing carefully the surrounding areolar tissue, he attached to each extremity a glass tube, by means of which he kept up a current of warm water within it. He then placed the vein in a slightly acid liquor, and carefully collected the fluid of the current. During the first few minutes, it exhibited no change; but, in five or six minutes, became sensibly acid. This experiment was repeated on veins taken from the human subject with like results; and not only on veins but on arteries.

Similar experiments were next made on living animals. He took a young dog, about six weeks old, whose vessels were thin, and, consequently, better adapted for the success of the experiment, and exposed one of its jugular veins. From this he dissected entirely the surrounding matter, and especially the areolar tissue, and the minute vessels that ramified upon it; and placed it upon a card, in order that there

[1] Op. citat., ii. 273.

might be no point of contact between it and the surrounding parts. He then let fall upon its surface and opposite the middle of the card a thick watery solution of nux vomica,—a substance, that exerts a powerful action on dogs. He took care, that no particle of the poison touched any thing but the vein and cord; and that the course of the blood, within the vessel, was free. Before the expiration of three minutes, the effects he expected appeared,—at first feebly, but afterwards with so much activity, that to prevent fatal results he had to inflate the lungs. The experiment was repeated on an older animal with the same results; except that, as might have been expected, they were longer in exhibiting themselves, owing to the greater thickness of the parietes of the veins.

Satisfied, as regarded the veins, he now directed his attention to the arteries:—the results were the same. They were, however, slower in appearing than in the case of the veins, owing to the tissue of the arteries being less spongy. It required upwards of a quarter of an hour for imbibition to be accomplished. In one of the rabbits, which died under the experiment, they had an opportunity of discovering, that absorption could not have been effected by any small veins, that had escaped dissection. One of the carotids,—the subject-vessel of the experiment,—was taken from the body; and the small quantity of blood, adherent to its inner surface, was found by M. Magendie, and his friends who assisted at the experiment, to possess the extreme bitterness that characterizes nux vomica. These experiments were sufficient to prove the fact of imbibition by the large vessels, both in the dead and in the living state. His attention was now directed to the smaller; which seemed, *à priori*, favourable to the action, from their delicacy of organization. He took the heart of a dog, that had died the day before, and injected water, of the temperature of 86° of Fah., into one of the coronary arteries, which readily returned by the coronary vein into the right auricle, whence it was allowed to flow into a vessel. Half an ounce of water, slightly acidulated, was now placed in the pericardium. At first, the injected fluid did not exhibit any signs of acidity; but, in five or six minutes, the evidences were unequivocal.

From these facts, M. Magendie[1] draws the too exclusive deduction, that "all bloodvessels, arterial and venous, dead or living, large or small, possess a physical property capable of accounting for the principal phenomena of absorption." We shall endeavour to show, that it explains only certain varieties of absorption,—those in which the vessel receives the fluid unmodified,—but that it is unable to account for other absorption in which an action of selection and elaboration is necessary.

After these experiments were performed, others were instituted by MM. Ségalas[2] and Fodéra,[3] from which the latter physiologist attempts to show, that exhalation is simply a *transudation* of substances from the interior of vessels to the exterior; and absorption an *imbibition* or passage of fluids from the exterior to the interior. The facts adduced by

[1] Précis, &c., ii. 283.
[2] Magendie's Journal de Physiol., ii. 217.
[3] Recherches Expériment. sur l'Absorption, &c., Paris, 1824, and Magendie's Journal, &c., iii. 35.

M. Fodéra in support of his views will be considered under the head of SECRETION. They go chiefly to show the facility with which substances penetrate the parietes of vessels and other tissues of the body; an action which he found to be singularly accelerated by the galvanic influence. Prussiate of potassa was injected into the cavity of the pleura; and sulphate of iron introduced into that of the peritoneum in a living animal. Under ordinary circumstances, it requires five or six minutes before the two substances meet by imbibition through the diaphragm; but the admixture is instantaneous if the diaphragm be subjected to a slight galvanic current. The same fact is observed, if one of the liquids be placed in the urinary bladder, and the other in the abdomen; or the one in the lung, and the other in the cavity of the pleura. It was further found, that, according to the direction of the current, the union took place in the one or the other cavity. Dr. Bostock,[1] in commenting on these cases, thinks it must be admitted, that they "go very far to prove that membranes, *perhaps even during life*, and certainly after death, before their texture is visibly altered, have the power of permitting the transudation of certain fluids." That such imbibition occurs during life, appears to be indisputably proved. If the clear and decisive experiments of Magendie and Fodéra were insufficient, the additional testimony,—afforded by Lawrence, Coates, and Harlan; by Dutrochet, Faust, Mitchell, Rogers, Draper, and others,—would command it. By the different rates of penetrativeness of different fluids, and of permeability of different tissues, we can explain why imbibition may occur in one set of vessels and not in another; and the constant current, established in the interior of the vessel is a sufficient reply to the suggestion, that there may not be the same tendency to transude after the fluid has entered it. M. Adelon[2] is of opinion, that under the view of imbibition we ought to find substances in the arteries and lymphatics also; but a sufficient objection to this would be,—the comparative tardiness, with which the former admit the action; and the selection, and, consequently, refusal, exerted by the latter; but even here evidences of adventitious imbibition are occasionally met with; as in the case of salts, which—we have seen—have been detected in the thoracic duct, after having been introduced into the cavity of the abdomen.

The two following experiments by Prof. J. K. Mitchell,[3] which are analogous to numerous others, performed in the investigation of this subject, well exhibit endosmose in living tissues. A quantity of a solution of acetate of lead was thrown into the peritoneal cavity of a young cat; sulphuretted hydrogen being passed, at the same time, into the rectum. In four minutes, the poisonous gas killed the animal. Instantly on its death, the peritoneal coat of the intestines, and the parietes of the cavity in contact with them, were found lined with a metallic precipitate, which adhered to the surface, and was removable by nitric acid moderately diluted. It was the characteristic precipitate of sulphuretted hydrogen, when acting on lead. In another experiment on a cat, a solution of acetate of lead was placed in the thorax, and sulphuretted hydrogen in the abdomen. Almost immediately after the entrance of

[1] Physiology, edit. cit., p. 629. [2] Op. cit.
[3] American Journal of the Medical Sciences, vii. 44, Philada., 1830.

the sulphuretted hydrogen into the abdominal cavity, death ensued. On inspecting the thoracic side of the diaphragm, which was done as quickly as possible, the tendinous part of it exhibited the leaden appearance of the precipitate thrown down by sulphuretted hydrogen. The experiment of J. Müller, referred to in a preceding page, establishes the same fact.

It may be concluded, then, that all living tissues imbibe liquid matters which come in contact with them; and that the same occurs to solids, provided they are soluble in the humours, and especially in the serum of the blood. But although imbibition is doubtless effected by living tissues, too great a disposition has been manifested to refer all the vital phenomena of absorption and exhalation to it. Even dead animal membrane has been supposed to exert a positive agency in respect to bodies placed on either side of it. In the early part of this work[1] the phenomena of imbibition were investigated, and it was there explained how endosmose and exosmose are effected through organic membranes. A careful examination of those phenomena would lead to the belief, that in many cases the membrane exerts no agency except in the manner last suggested by M. Dutrochet. This is signally manifested in experiments with porous, inorganic substances; and it has been ingeniously and ably confirmed by Dr. Draper,[2] of New York, who found, that the phenomena were elicited, when, instead of an organic tissue, fissured glass was employed. Still, as has been demonstrated, the nature of the septum or membrane has in other cases a marked effect on endosmose.

Sir David Barry,[3]—in different memoirs laid before the *Académie Royale de Médecine*, the *Académie Royale des Sciences* of Paris, and the *Medico-Chirurgical Society* of London,—maintained, that the whole function of external absorption is a physical result of atmospheric pressure; and "that the circulation in the absorbing vessels and in the great veins depends upon this same cause in all animals possessing the power of contracting and dilating a cavity around that point to which the centripetal current of their circulation is directed." In other words, it is his opinion, that, at the time of inspiration, a tendency to a vacuum is produced in the chest by its expansion; and as the atmospheric pressure externally thus ceases to be counterbalanced, the pressure without occasions the flow of blood towards the heart along the veins. The consideration of the forces that propel the blood will afford us an opportunity of saying a few words on this view; at present, we may only observe, that Sir David ascribes absorption,—which he explicitly states to be, in his opinion, extra vital,—to the same cause. In proof of this, he instituted numerous experiments, in which the absorption of poisons from wounds appeared to take place, or to be suspended, according as the wounds were, as he conceived, exposed to atmospheric pressure, or freed from its influence by the application of a cupping-glass. The same quantity of poison, which, under ordinary

[1] See p. 65.

[2] Amer. Journ. of the Med. Sciences, for Aug., 1836, p. 276; Nov., 1837, p. 122; May, 1838, p. 23, and August, 1838—more especially the two last.

[3] Experimental Researches on the Influence of Atmospheric Pressure upon the Circulation, &c., Lond., 1826.

circumstances, destroyed an animal in a few seconds, was rendered completely innocuous by the exhausted glass; and what is singular, even when the symptoms had commenced, the application of the cupping-glass had the effect of speedily and completely removing them;—a fact of essential importance in its therapeutical relations. In commenting on the conclusions of Sir D. Barry, Messrs. Addison and Morgan,[1]—who maintain the doctrine, that all poisonous agents produce their specific effects upon the brain, and general system, through the sentient extremities of nerves, and through the sentient extremities of nerves only; and that, when such agents are introduced into the current of the circulation in any way, their effects result from the impression made upon the sensible structure of the bloodvessels, and not from their direct application to the brain itself,—contend, that the soft parts of the body, when covered by an exhausted cupping-glass, must necessarily, from the pressure of the edges of the glass, be deprived for a time of all connexion, both nervous and vascular, with the surrounding parts;—that the nerves must be partially or altogether paralysed by compression of their trunks; and that, from the same cause, all circulation through the veins and arteries within the area of the glass, must cease; that the rarefaction of the air within the glass being still farther increased by means of the small pump attached to it, the fluids, in the divided extremities of the vessels, are forced into the vacuum, and, with these fluids, either a part or the whole of the poison, which had been introduced; and that, in such a condition of parts, the compression, on the one hand, and the removal of the poison from the wound on the other, will sufficiently explain the result of the experiment, either according to the views of those who conceive the impression to be made on the nerves of the bloodvessels, or of those who think, that the agent must be carried along with the fluid of the circulation to the part to be impressed.

Thus far allusion has been made only to the passage of tenuous fluids into the veins. Insoluble substances have, however, been detected by Professor Oesterlen[2] in the mesenteric veins. On administering levigated charcoal to animals for five or six days in succession, the blood of these veins exhibited distinctly particles of charcoal of different sizes, some of them so large, that it was a matter of surprise how they could have made their way into the blood through the epithelium, mucous membrane and the walls of the bloodvessels. We have no difficulty, consequently, in comprehending how the mild chloride and other insoluble preparations of mercury may be able to enter the bloodvessels in this manner.

Such would seem to be the main facts regarding the absorbent action of the veins, which rests on as strong evidence as we possess regarding any of the functions of the body; yet, in the treatise on Animal and Vegetable Physiology by Dr. Roget,[3] we find it passed by without a comment!

We have still to inquire into the agents of internal and adventitious absorption.

[1] An Essay on the Operation of Poisonous Agents upon the Living Body, Lond., 1829.
[2] Heller's Archiv., Bd. iv. Heft 1, cited in Lond. Med. Gazette for July, 1847.
[3] Bridgewater Treatise, Lond., 1834, Amer. edit., Philad., 1836.

IV. INTERNAL ABSORPTION.

On this point but few remarks will be necessary, after the exposition of the different vascular actions concerned in absorption. The term comprehends *interstitial absorption*, and the *absorption of recrementitial fluids*. The *first* comprises the agency by which the different textures of the body are decomposed and conveyed into the mass of blood. It will be considered more at length under the head of NUTRITION; the *second*, that of the various fluids effused into cavities; and the *third*, that which is effected on the excretions in their reservoirs or excretory ducts. All these must be accomplished by one of the two sets of vessels previously described; lymphatics, or veins, or both. Now, we have attempted to show, that an action of selection and elaboration is exerted by lymphatics; whilst we have no evidence of such action in the case of the veins. It would follow, then, that all the varieties of internal absorption, in which the substance, when received into the vessel, possesses different characters from those it had when without, must be executed by lymphatics; whilst those, in which no conversion occurs, take place by the veins. In the constant absorption, and corresponding deposition, incessantly going on in the body, the solid parts must be reduced to their elements, and a new compound be formed; inasmuch as we never find bone, muscle, cartilage, membrane, &c., existing in these states in any of the absorbed fluids; and it is probable, therefore, that, at the radicles of the lymphatic vessels, they are converted into the same fluid—the lymph—in like manner as the heterogeneous substances in the intestinal canal afford to the lacteals the elements of a fluid the character of which is always identical. On the other hand, when the recrementitial fluid consists simply of the serum of the blood, more or less diluted, there can be no obstacle to the passage of its aqueous portion immediately through the coats of the veins by imbibition, whilst the more solid part is taken up by the lymphatic vessels. In the case of excrementitious fluids, there is reason to believe, that absorption simply removes some of their aqueous portions; and this, it is obvious, can be effected directly by the veins, through imbibition. The facts, connected with the absorption of substances from the interior of the intestine, have clearly shown, that the chyliferous vessels alone absorb chyle, and that the drinks and adventitious substances pass into the mesenteric veins. These apply, however, to *external* absorption only; but similar experiments and arguments have been brought forward by the supporters of the two opinions, in regard to substances placed on the peritoneal surface of the intestine, and other parts of the body. Whilst some affirm, that they have entered the lymphatics; others have only been able to discover them in the veins. Mr. Hunter, having injected water coloured with indigo into the peritoneal cavity of animals, saw the lymphatics, a short time afterwards, filled with a liquid of a blue colour. In animals, that had died of pulmonary or abdominal hemorrhage, Mascagni found the lymphatics of the lungs and peritoneum filled with blood; and he asserts, that, having kept his feet for some hours in water, swelling of the inguinal glands supervened, with transudation of a fluid through the gland; coryza, &c. M. Desgenettes

observed the lymphatics of the liver containing a bitter, and those of the kidneys a urinous, lymph. Sömmering detected bile in the lymphatics of the liver; and milk in those of the axilla. M. Dupuytren relates a case, which M. Magendie conceives to be much more favourable to the doctrine of absorption by the lymphatic vessels than any of the others. A female, who had an enormous fluctuating tumour at the upper and inner part of the thigh, died at the Hôtel Dieu, of Paris, in 1810. A few days before her death, inflammation occurred in the subcutaneous areolar tissue at the inner part of the tumour. The day after dissolution, M. Dupuytren opened the body. On dividing the integuments, he noticed white points on the lips of the incision. Surprised at the appearance, he carefully dissected away some of the skin, and observed the subcutaneous areolar tissue overrun by whitish lines, some of which were as large as a crow's quill. These were evidently lymphatics filled with puriform matter. The glands of the groin, with which these lymphatics communicated, were injected with the same matter. The lymphatics were full of the fluid, as far as the lumbar glands; but neither the glands nor the thoracic duct presented any trace of it.[1] On the other hand, multiplied experiments have been instituted, by throwing coloured and odorous substances into the great cavities of the body; and these have been found always in the veins, and never in the lymphatics.

To the experiments of Mr. Hunter, objections have been urged, similar to those brought against his experiments to prove the absorption of milk by the lacteals; and sources of fallacy have been pointed out. The blue colour, which the lymphatics seemed to him to possess, and which was ascribed to the absorption of indigo, was noticed in the experiments of Messrs. Harlan, Lawrence, and Coates;[2] but they discovered that this was an optical illusion. What they saw was the faint blue, which transparent substances assume, when placed over dark cavities. Mr. Mayo[3] has also affirmed that the chyliferous lymphatics always assume a bluish tint a short time after death, even when the animal has not taken indigo. The cases of purulent matter, &c., found in the lymphatics, may be accounted for by the morbid action having produced disorganization of the vessel, so that the fluid could enter the lymphatics directly; and, if once within, its progression could be readily understood.

M. Magendie[4] asserts, that M. Dupuytren and he performed more than one hundred and fifty experiments, in which they submitted to the absorbent action of serous membranes different fluids, and never found any of them within the lymphatic vessels. These fluids produced their effects more promptly, in proportion to the rapidity with which they were capable of being absorbed. Opium exerted its narcotic influence; wine produced intoxication, &c., and M. Magendie found, from numerous experiments, that the ligature of the thoracic duct in no respect diminished the promptitude with which these effects supervened. The

[1] Magendie, Précis, &c., 2de édit., ii. 195, et seq.; and Adelon, art. Absorption, Dict. de Méd., 2de édit., i. 239, and Physiologie de l'Homme, 2de édit., iii. 65, Paris, 1829.
[2] Harlan's Physical Researches, p. 459, Philad., 1835.
[3] Outlines of Human Physiology, 3d edit., Lond., 1833.
[4] Op. cit., ii. 211.

partisans of lymphatic absorption, however, affirm that even if these substances are met with in the veins, it by no means follows, that absorption has been effected by them; for the lymphatics, they assert, have frequent communications with the veins; and, consequently, they may still absorb and convey their products into the venous system. In reply to this, it may be urged, that all the vessels—arterial, venous, and lymphatic—appear to have intercommunication; but there is no reason to believe, that the distinct offices, performed by them, are, under ordinary circumstances, interfered with; and, again, where would be the necessity for these intermediate lymphatic vessels, seeing that imbibition is so readily effected by the veins? The axiom—*quod fieri potest per pauca, non debet fieri per multa*—is here strikingly appropriate. The lymphatics, too, as we have endeavoured to show, exert an action of selection and elaboration on substances exposed to them; but, in the case of venous absorption, there is not the slightest evidence, that any such selection exists,—odorous and coloured substances retaining, within the vessel, the properties they had without. Lastly. Where would be the use of organs of a distinct lymphatic circulation opening into the thoracic duct, seeing that the absorbed matters might enter the various venous trunks directly through these supposititious communicating lymphatics; and ought we not occasionally to be able to detect in the lymphatic trunks some evidence of those substances, which their fellows are supposed to take up and convey into the veins? These carrier lymphatics have obviously been devised to support the tottering fabric of exclusive lymphatic absorption,—undermined, as it has been, by the powerful facts and reasonings that have been adduced in favour of absorption by veins.

From the whole of the preceding history of absorption, we are of opinion, that the chyliferous and lymphatic vessels form only chyle and lymph, refusing all other substances, with the exception of saline and other matters, that enter probably by imbibition,—that the veins admit every liquid, which possesses the necessary tenuity; and that whilst all the absorptions, which require the substances acted upon to be decomposed and transformed, are effected by chyliferous and lymphatic vessels; they that are sufficiently thin, and demand no alteration, are accomplished directly through the coats of the veins by imbibition; and we shall see that such is the case with several of the transudations or exhalations.

V. ACCIDENTAL ABSORPTION.

The experiments, to which reference has been made, have shown, that many substances, adventitiously introduced into various cavities, or placed in contact with different tissues, have been rapidly absorbed into the blood, without experiencing any transformation. Within certain limits, the external envelope of the body admits of this function; but by no means to the same extent as its prolongation, which lines the different excretory ducts. The absorption of drinks is sufficient evidence of the activity of the function as regards the gastro-enteric mucous membrane. The same may be said of the pulmonary mucous membrane. Through it, oxygen and nitrogen pass to reach the blood in the lungs, as

well as carbonic acid in its way outwards. Aromatic substances, such as spirit of turpentine, breathed for a time, are detected in the urine; proving that their aroma has been absorbed; and it is by absorption, that contagious miasmata probably produce their pestiferous agency. Dr. Madden,[1] however, thinks that the lungs do not absorb watery vapour with the rapidity, or to the extent, that has been imagined; whilst Dr. A. Combe[2] hazards the hypothesis, that owing apparently to the extensive absorption of aqueous vapour by the lungs, the inhabitants of marshy and humid districts, as the Dutch, are remarkable for the predominance of the lymphatic system.

Not only do the tissues, as we have seen, suffer imbibition by fluids, but by gases also: the experiments of Chaussier and Mitchell astonish us by the rapidity and singularity of the passage of the latter through the various tissues;—the rapidity varying according to the permeability of the tissue, and the penetrative power of the gas.

a. *Cutaneous Absorption.*

On the subject of *cutaneous absorption*, much difference of sentiment has prevailed;—some asserting it to be possible to such an extent, that life may be preserved, for a time, by nourishing baths. It has also been repeatedly affirmed, that rain has calmed the thirst of shipwrecked mariners who have been, for some time, deprived of water. It is obvious, from what we know of absorption, that, in the first of these cases, the water only could be absorbed; and even the possibility of this has been denied by many. Under ordinary circumstances, it can happen to a trifling extent only, if at all; but, in extraordinary cases, where the system has been long devoid of its usual supplies of moisture, and where we have reason to believe, that the energy of absorption is increased, such imbibition may be possible. Sanctorius,[3] Von Gorter,[4] Keill,[5] Mascagni,[6] Madden,[7] R. L. Young,[8] Dill,[9] and others believe, that this kind of absorption is not only frequent but easy. It has been affirmed, that after bathing the weight of the body has been manifestly augmented; and the last of these individuals has adduced many facts and arguments to support the position. Strong testimony has been brought forward in favour of extensive absorption of moisture from the atmosphere. This is probably effected rather through the pulmonary mucous surface than the skin. A case of ovarian dropsy is referred to by Dr. Madden,[10] in which the patient, during eighteen days, drank 692 ounces of fluid; and discharged by urine and paracentesis 1298 ounces, being an excess of 606 ounces of fluid egesta over the fluid ingesta. Bishop Watson, in his Chemical Essays, states, that a lad at Newmarket, having been almost starved, in order that he might be reduced to the proper weight for riding a match, was weighed at 9, and again at 10, A. M., when he was found to have gained nearly 30

[1] Experimental Inquiry into the Physiology of Cutaneous Absorption, p. 64, Edinb., 1838.
[2] Principles of Physiology applied to the Preservation of Health, 5th edit, p. 72, Edinb., 1836.
[3] De Static. Medic., Lugd. Bat., 1711.
[4] De Perspirat. Insensib., Lugd. Bat., 1736.
[5] Tentamin. Medico-Physic., Lond., 1718.
[6] Vas. Lymphat. Hist., Senis, 1783.
[7] Op. cit., p. 58.
[8] De Cutis Inhalatione, Edinb., 1813.
[9] Edinb. Medico-Chir. Transact., ii. 350.
[10] Op. cit., p. 55.

ounces in weight in the interval, although he had only taken half a glass of wine. Dr. Carpenter[1] gives a parallel case, which was related to him by Sir G. Hill, Governor of St. Vincent. A jockey had been for some time in training for a race in which Sir G. Hill was much interested, and had been reduced to the proper weight. On the morning of the race, suffering much from thirst, he took one cup of tea, and shortly afterwards his weight was found to have increased six pounds, so that he was incapacitated for riding. These cases certainly appear difficult of belief: yet the authority is good. Dr. Carpenter presumes, that nearly the whole of the increase in Bishop Watson's case, and at least three fourths of it in Sir G. Hill's case, must be attributed to cutaneous absorption, which was probably stimulated by the wine that was taken in the one, and by the tea in the other. Bichat was under the impression, that, in this way he imbibed the tainted air of the dissecting room, in which he passed a large portion of his time. To avoid an objection, that might be urged against this idea,—that the miasmata might have been absorbed by the air passages, he so contrived his experiment, as, by means of a long tube, to breathe the fresh outer air; when he found, that the evidence, which consisted in the alvine evacuations having the smell of the miasmata of the dissecting-room, continued. It is obvious, however, that such an experiment would hardly admit of satisfactory execution, and it is even doubtful, whether there was any actual relation between the assigned effect and the cause. The testimony of MM. Andral, Boyer, Duméril, Dupuytren, Serres, Lallemand, Ribes, Lawrence, Parent-Duchatelet, and that afforded by the author's own observation, are by no means favourable to the great unwholesomeness of cadaveric exhalations.[2]

Dr. J. Bradner Stuart[3] found, after bathing in infusions of madder, rhubarb, and turmeric, that the urine was tinged with these substances. A garlic plaster affected the breath, when every care was taken, by breathing through a tube connected with the exterior of the apartment, that the odour should not be received into the lungs. Dr. Thomas Sewall[4] found the urine coloured, after bathing the feet in infusion of madder, and the hands in infusions of madder and rhubarb. Dr. Mussey[5] proved, that if the body be immersed in a decoction of madder, the substance may be detected in the urine, by using an appropriate test. Dr. Barton found, that frogs, confined in dry glass vessels, became enfeebled, diminished in size, and unable to leap; but that, on the introduction of a small quantity of water, they soon acquired their wonted vigour, became plump, and as lively as usual in their motions.[6] M. W. F. Edwards[7] of Paris, is, also, in favour of absorption being carried on by the skin to a considerable extent.

[1] Human Physiology, § 462, Lond., 1842.

[2] Parent-Duchatelet, Hygiène Publique, Paris, 1836; and the remarks of the author in his Human Health, p. 77, Philad., 1844.

[3] New York Med. Repos., vols. i. and iii. 1810-11.

[4] Med. and Physical Journ., xxxi. 80, Lond., 1814.

[5] Philad. Medical and Physical Journal, i. 288, Philad., 1808.

[6] Klapp, Inaugural Essay on Cuticular Absorption, p. 30, Philad., 1805.

[7] Sur l'Influence des Agens Physiques; or Drs. Hodgkin and Fisher's translation, p. 61, and p. 187, &c., Lond., 1832.

To deny cutaneous absorption altogether is impossible. It is a channel, in fact, by which we introduce one of our most active remedial agents into the system;—and it has not unfrequently happened, where due caution has been omitted, that the noxious effects of different mineral and other poisons have been developed by their application to the surface, but it is by no means common or easy, when the cuticle is sound, unless the substance employed possesses unusually penetrating properties. M. Chaussier found, that to kill an animal, it is sufficient to make sulphuretted hydrogen gas act on the surface of the body, taking care that none gets into the air-passages; the researches of Prof. J. K. Mitchell[1] have also shown that this gas is powerfully penetrant. Unless, however, the substances, in contact with the epidermis, are of such a nature as to attack its chemical composition, there is usually no extensive absorption.

It is only of comparatively late years, that physiologists have ventured to deny, that the water of a bath, or the moisture from a damp atmosphere, is taken up under ordinary circumstances; and if, in such cases, the body appears to have increased in weight, it is affirmed, and with some appearance of truth, that this may be owing to diminution of the cutaneous transpiration. It is, indeed, probable, that one great use of the epidermis is to prevent the inconveniences to which we should necessarily be liable, were such absorption easy. This is confirmed by the fact, that if the skin be deprived of the epidermis, and the vessels that creep on the outer surface of the true skin be thus exposed, absorption occurs as rapidly as elsewhere. J. Müller affirms, that saline solutions applied to the corium penetrate the capillaries in a second of time. To insure this result in inoculation and vaccination, the matter is always placed beneath the cuticle; and, indeed, the small vessels are generally slightly wounded, so that the virus gets immediately into the venous blood. Yet—it is proper to remark—the lizard, whose skin is scaly, after having lost weight by exposure to air, recovers its weight and plumpness when placed in contact with water; and if the scaly skin of the lizard permits such absorption, M. Edwards thinks it impossible not to attribute this property to the cuticle of man. When the epidermis is removed, and the system is affected by substances placed in contact with the true skin, we have the *endermic method* of medication.

M. Séguin[2] instituted a series of experiments to demonstrate the absorbent or non-absorbent action of the skin. His conclusion was, that water is not absorbed, and that the epidermis is a natural obstacle to the action. To discover, whether this was the case as regarded other fluids, he experimented on individuals labouring under venereal affections, who immersed their feet and legs in a bath, composed of sixteen pints of water and three drachms of corrosive chloride of mercury, for an hour or two, twice a day. Thirteen, subjected to the treatment for twenty-eight days, gave no signs of absorption; the fourteenth was manifestly affected, but he had itchy excoriations on the legs; and the

[1] Amer. Journal of the Med. Sciences, vii. 44; and p. 68 of this work.
[2] Annales de Chimie, xc. 185.

same was the case with two others. As a general rule, absorption exhibited itself in those only whose epidermis was not in a state of integrity. At the temperature of 74° Fahrenheit, however, the sublimate was occasionally absorbed, but never the water. From other experiments, it appeared evident, that the most irritating substances, and those most disposed to combine with the epidermis, were partly absorbed, whilst others were apparently not. Having weighed a drachm (seventy-two grains, *poids de marc*) of calomel, and the same quantity of camboge, scammony, salt of alembroth, and tartar emetic, M. Séguin placed an individual on his back, washed the skin of the abdomen carefully, and applied to it these substances at some distance from each other, covering each with a watch-glass, and maintaining the whole *in situ* by a linen roller. The heat of the room was kept at 65°. M. Séguin remained with the patient, in order that the substances should not be displaced: and he protracted the experiment for ten hours and a quarter. The glasses were then removed, and the substances carefully collected and weighed. The calomel was reduced to 71½ grains. The scammony weighed 71⅗; the camboge, 71; the salt of alembroth, 62 grains,[1] and the tartar emetic 67 grains.[2]

It requires, then, in order that matters shall be absorbed by the skin, that they shall be kept in contact with it, so as to penetrate its pores, or the channels by which the cutaneous transpiration exudes; or else that they shall be forced through the cuticle by friction,—the *iatraleptic mode.* In this way, the substance comes in contact with the cutaneous vessels, and enters them probably by imbibition. Certain it is, that mercury has been detected in the venous blood by Colson, Christison, Cantu, Autenrieth, Zeller, Schubarth, and others.[3]

Not long after the period that M. Séguin was engaged in his experiments, Dr. Rousseau,[4] of Philadelphia, contested the existence of absorption through the epidermis, and attempted to show, in opposition to the experiments we have detailed, that the pulmonary organs, and not the skin, are the passages by which certain substances enter the system. By cutting off all communication with the lungs, which he effected by breathing through a tube communicating with the atmosphere on the outside of the chamber, he found, that although the surface of the body was bathed with the juice of garlic, or the spirit of turpentine, none of the qualities of these fluids could be detected, either in the urine, or the serum of the blood. From subsequent experiments, performed by Dr. Rousseau, assisted by Dr. Samuel B. Smith,[5] and many of which Professor Chapman[6] witnessed, the following results were deduced. *First,* That of all the substances employed, madder and rhubarb were those only that affected the urine,—the latter of the two more readily entering the system; and *secondly,* that the power of absorption is limited to a very small portion of the surface of the body.

[1] Several pimples were excited on the part to which it was applied.
[2] Magendie's Précis, &c., ii. 262.
[3] The author's General Therapeutics and Materia Medica, 4th edit., i. 90, Philad., 1850.
[4] Experimental Dissert. on Absorption, Philad., 1800.
[5] Philad. Medical Museum, i. 34, Philad., 1811.
[6] Elements of Therapeutics and Materia Medica, 6th edit., i. 65, Philad., 1831.

The only parts, indeed, that seemed to possess it, were the spaces between the middle of the thigh and hip, and between the middle of the arm and shoulder. Topical bathing, with a decoction of rhubarb or madder, and poultices of these substances applied to the back, abdomen, sides, or shoulders, produced no change in the urine; nor did immersion of the feet and hands for several hours in a bath of the same materials afford the slightest proof of absorption.

From these and other facts, sufficiently discrepant it is true, we are justified in concluding, that cuticular absorption, under ordinary circumstances, is not easy; but we can readily conceive, from the facility with which water soaks through animal tissues, that if the animal body be immersed sufficiently long in it, and especially if the vessels have been previously drained, imbibition may take place to a considerable extent. This, however, would be a physical absorption, and might be effected as well in the dead as in the living body.

b. *Other Accidental Absorptions.*

Amongst the adventitious absorptions have been classed all those that are exerted upon substances retained in the excretory ducts, or situate in parts not natural to them. The bile, arrested in one of the biliary ducts, affords us, in jaundice, a familiar example of such absorption by the positive existence of bile in the bloodvessels; although the yellow colour has been gratuitously supposed to be caused by an altered condition of the red globules, and not by the presence of bile. This condition of the red globules would account for some of the symptoms,—as the yellow colour of the skin, and urine,—but it does not explain the clayey appearance, which the evacuations present, and which has been properly ascribed to the absence of the biliary secretion. We have, moreover, examples of this kind of absorption, where blood is effused into the areolar membrane, as in the case of a common sprain, or in those accumulations of fluid in various cavities, that are found to disappear by time;—the serous portion being taken up at first with some of the colouring matter, and, ultimately, the fibrin. In the case of accumulation of the serous fluid, that naturally lubricates cavities, it is of such a character—the aqueous portion at least—as to be imbibed with facility, and probably passes into the veins, in this manner,—the functions of exhalation and absorption consisting mainly, in such case, of transudation and imbibition.

But absorption is not confined to these fluids. It must, of course, be exerted on all morbid deposits; and it is to excite the action of the absorbents, that our remedial agents are directed. This absorption—in the case of solids—is of the interstitial kind; and, as the morbid formation has to undergo an action of elaboration, it ought to be referred to lymphatic agency.

To conclude the function of absorption:—All the products,—whether the absorption has been chyliferous, lymphatic, or venous,—are united in the venous system, and form part of venous blood. This fluid must, consequently, be variable in its composition, in proportion to the quantity of heterogeneous materials taken up by the veins, and the activity

of chyliferous and lymphatic absorption. It is also clear, that, between the parts of the venous system into which the supra-hepatic veins,—loaded with the products of intestinal absorption of fluids,—enter, and the opening of the thoracic duct into the subclavian, the blood must differ materially from that which flows in other parts of the system. All, however, undergo admixture in their passage through the heart; and all are converted into arterial blood by the function, that will next engage us,—RESPIRATION.

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